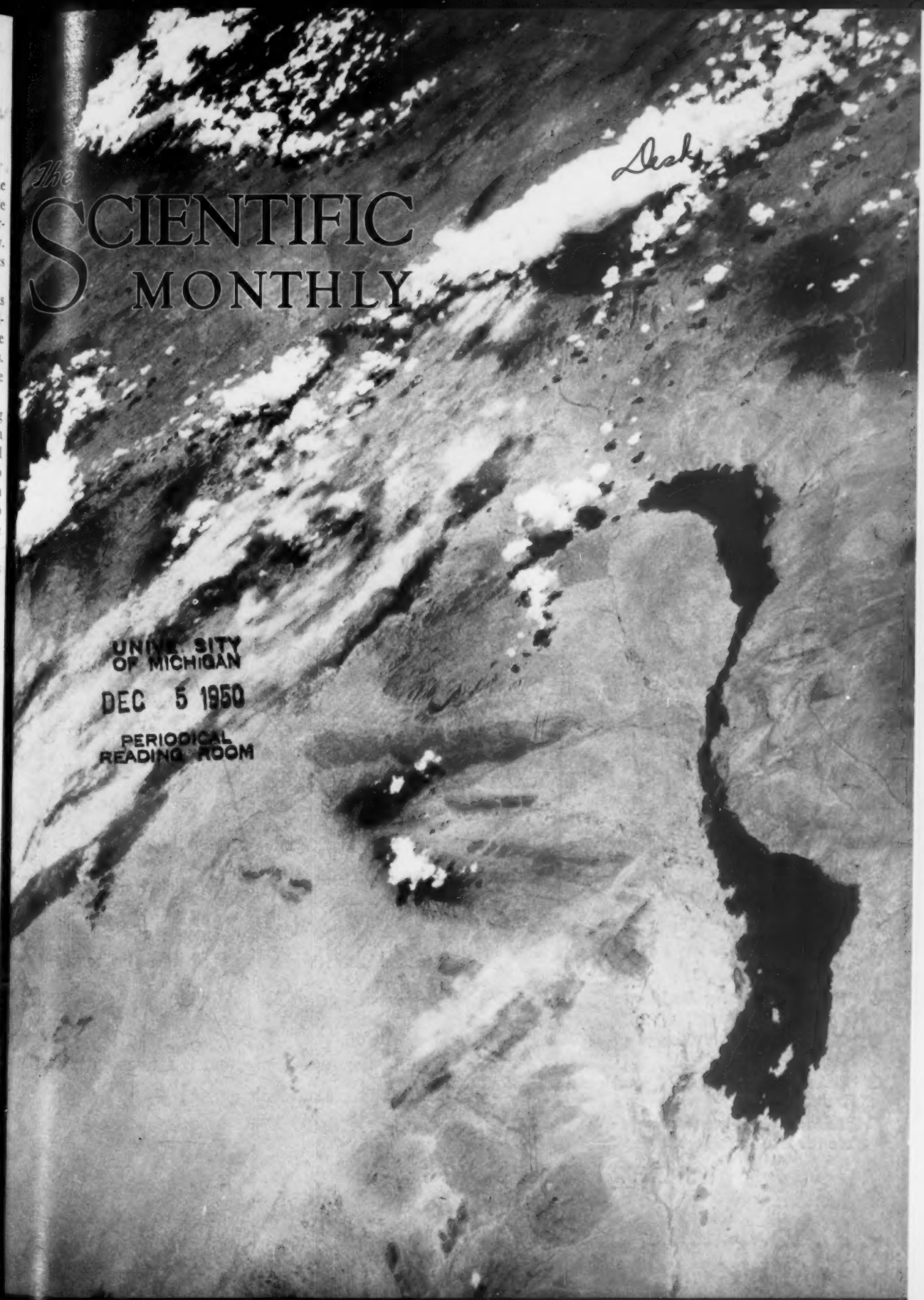

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THE SCIENTIFIC MONTHLY

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Science and Technology

(From the Month's News Releases)

Season's Greetings

Specialists in the photoperiodism of plants, experimenting with poinsettias, have found that this plant requires short days for prompt flowering. By starting cuttings October 1–10 and giving them daily dark periods of 14–16 hours (with no breaks), poinsettias will bloom and put out their bright bracts just in time for Christmas.

Fifty Christmas tree lights in plastic sockets will operate from a single electric outlet. When one bulb burns out, the others remain lighted, and there are no exposed contacts to cause short circuits.

"Scribbles" dolls have blank faces made of rigid plastic, making it possible for young artists to change the expression at will merely by wiping off the old face with tissue and drawing a new one. The doll body and its colorful costume are also made of washable plastic.

Bright-colored, three-dimensional scenes from Mother Goose, made without glass and with rounded edges, will not shatter if dropped or subjected to hard use. Rhymes are printed on the backs.

Gigantic snowflakes molded of styrene may be used in various decorative ways. Single snowflakes are 5½–9 inches in diameter and are $1.00–$6.00 each.

Teaching Aids

Teachers may secure free wall charts, illustrating by means of photographs how rubber is produced in southeast Asia, by writing to the Natural Rubber Bureau, 1631 K St., N.W., Washington 6, D. C. A map of the rubber-growing areas of southeast Asia and world production figures for 1900–1950 are included.

The new Westinghouse Teaching Aids Catalog describes 80 free and inexpensive charts, posters, booklets, and other audio-visual materials now available to junior and senior high-school teachers. These aids cover atomic energy, jet propulsion, electricity, radio, television, nutrition, home freezing, laundering, lighting, electric motors, and social studies. Each catalogue contains order blanks for use in requesting the materials desired. Teachers should write to School Service Department, Westinghouse Electric Corporation, 306 Fourth Ave., Box 1017, Pittsburgh 30, Pa., and ask for a free copy of B-4743. The School Service Department has also published a revised set of six nuclear physics charts that illustrate the most important areas of nuclear physics and explain in understandable terms how atomic energy is created, measured, and put to useful work. The booklet accompanying the charts (B-4143) supplies additional information on the topics discussed in the charts, as well as information on closely related topics. Charts and booklets are $1.00 per set.

A new topographic map of the Waldron, Arkansas, Quadrangle on which Geological Survey map makers have superimposed the latest shaded relief technique, has recently been issued. It is expected to be particularly useful in teaching. The shading, printed over brown contour lines, brings out relief in this mountainous region in a striking manner. Scaled at approximately one inch to the mile, and covering about 215 square miles, the map is available either with or without the shaded relief overprint. Purchasers should specify which edition is desired, and address the Director, U. S. Geological Survey, Washington 25, D. C. Single copies are 20 cents each. An index to topographic mapping in the United States or indexes to each of the 48 states, Alaska, Hawaii, and Puerto Rico may be obtained free upon request.

Vinylite plastic fashions a brilliantly colored relief map of the United States. This map costs far less than conventional relief maps of plaster, which are fragile, heavy, and usually custom-built. It measures 64″ × 40″—large enough to be seen from the back of a classroom—but weighs only 2¼ pounds. Dust and fingerprints can be easily wiped off with a damp cloth. The map is scaled at 1 inch to 50 miles, and vertical exaggeration, found on all relief maps, is 20 to 1.

CARE's Program

CARE packages can now be sent to: Austria, Belgium, Czechoslovakia, Finland, France, Germany (all 4 zones), Great Britain (England, Scotland, Wales, Northern Ireland), Greece, Israel, Italy, the Netherlands, Norway, Japan, Korea, Okinawa, Pakistan, the Philippine Islands, and Malta.

Food packages designated for one particular country may not be sent to another country. The special British food package is delivered only in England, Scotland, Wales, and Northern Ireland. The special Italian and Greek food packages are delivered only in the two countries for which they were designed. In its four years of operation, CARE has shipped overseas more than 9,000,000 packages, valued at approximately $100,000,000. The bulk of this, over 94 per cent, has been in food.

Contributions in any amount are accepted for CARE's "Food for Hungry Minds" program. Donations under $10 are pooled in a general fund for book purchases. Donors of $10 or more may specify the country, institution, and category of book. Delivery to institutions only, not individuals, in all CARE countries including Ceylon, Burma, Jordan, Thailand, and India (but not Israel and Okinawa). CARE's address is 20 Broad St., New York City 5.

In its investigation of building materials the National Bureau of Standards tests masonry walls by exposing them to the weather to determine the resistance of brick, tile, stucco, and mortar over a period of years.

THE
SCIENTIFIC MONTHLY

DECEMBER 1950

Oliver Heaviside: 1850–1925

SIR ROBERT WATSON-WATT

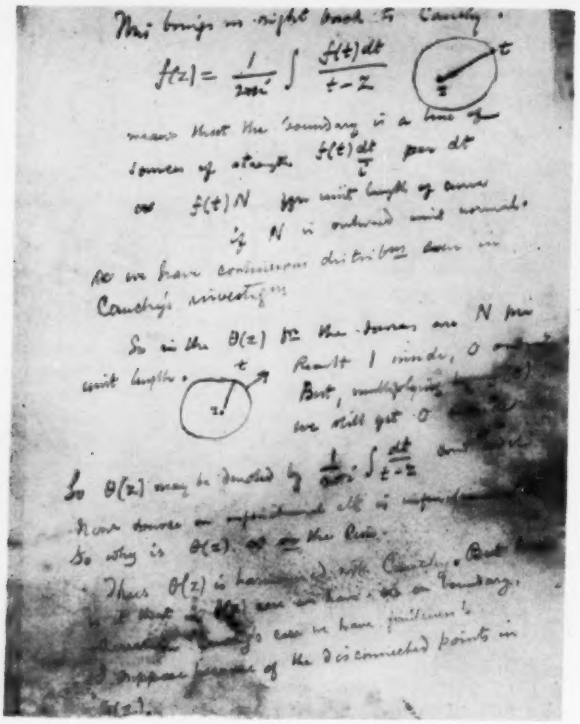
Sir Robert Watson-Watt is one of the few British civilians who have received the American Medal of Merit. Two days after Pearl Harbor he came to this country to work on Pacific Coast and Panama Canal defenses. In making the medal award in 1946 President Truman said of him that his "success attained in the military employment of these new scientific devices and methods inspired and stimulated the great radar program in the United States." After the war Sir Robert was concerned with radio aids to air and sea navigation, television, and the improvement of movie production. As scientific adviser on telecommunications to the British Ministries of Air, Supply, Transport, and Civil Aviation, his responsibilities affected the whole of Britain's civil air and sea transport and military aviation.

HE WAS a stranger, but to some who were attuned to him, a very attractive person." When it was proposed, Oliver Heaviside then being sixty-eight years old, to give him a U. S. honor, an American engineer said, "Heaviside? Is he still living? I thought he was one of the classics!" He *was* still living, and he *was* already one of the classics. Of no other indubitably great man would it be more difficult to decide whether he would have taken the remark itself as a high honor. But at least he quoted it himself. No equally great man of his time would have taken his first automobile ride in 1925, when he was seventy-five. Grimly enough, this first experience of motor transport, which he found interesting and comfortable, was the last. It started from his hermit cell which, characteristically and unromantically, was a conventional English villa, with gas lighting and (inadequate) gas heating. It finished at the nursing home where, a month later, he was to take leave of a world to which he had given much, from which he had taken pathetically little.

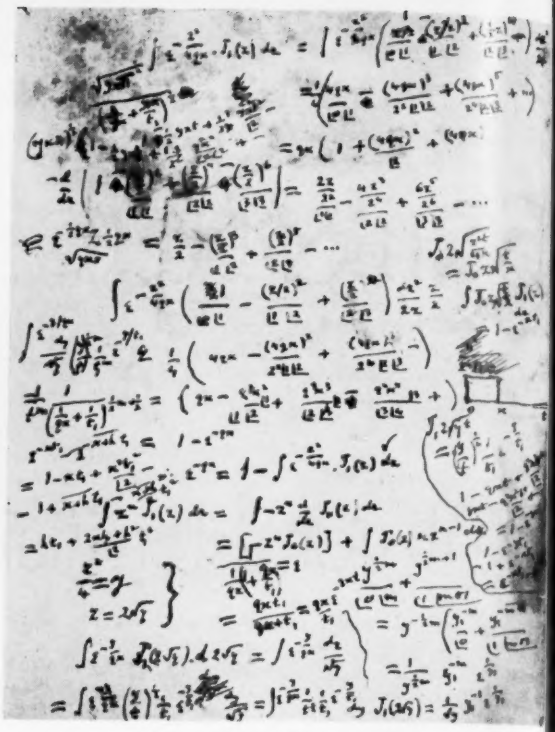
Thus passed the "old odd and impish Oliver," "unwilling to receive kindness" or "any help which he thought was in any way charitable," yet demanding and exacting of anyone who had elected to serve him. This later "man of average height but much above the average in appearance . . . face strikingly handsome, with brilliant eyes, fine teeth and a most remarkable white head of hair . . . gracious bearing and manners of a gentleman of the old school . . . indeed the type of old scholar one is wont to picture;" this continuing "master of sarcasm" "with an unquenchable spirit of fun;" this earlier "short red-haired Englishman of autocratic disposition and of superb powers of mental penetration and intuition"—what did he leave us, as the only monuments he would have wished to have?

Professor E. T. Whittaker speaks for the mathematicians with whom Heaviside was often at war:

> Looking back on the controversy after thirty years, we should now place the Operational Calculus with Poincaré's discovery of automorphic functions and Ricci's discovery of the Tensor Calculus as the three most important mathematical advances of the last quarter of the nineteenth century. Applications, extensions and justifica-



Oliver Heaviside's pencil notes.



Oliver Heaviside's ink notes.

tions of it constitute a considerable part of the mathematical activity of today.

The mathematical physicists stand, perhaps a little uneasily, between the austere purities of the "real mathematicians" and the well-ordered curiosity of the physicists *tout court,* who, with the child Clerk-Maxwell, want to know "What's the go of it?" They look with more sympathy than do their purer brethren on the fertile earthiness of the engineers, who want to "direct the forces of nature for the use and convenience of man." And so the mathematical physicists would admit Heaviside's claim to a place in their particular Pantheon, because of the way, the uniquely lively and irreverent way, in which he clarified Clerk-Maxwell's symbolism, and in his engaging, disturbing, and provocative volumes *Electromagnetic Theory* gave much added flexibility to the application and extension of Clerk-Maxwell's work, as did Maxwell to that of the inspired mechanical imagery of Faraday, "the father of them all."

Perhaps even of Faraday would a contemporary Doetsch have said, as the Doetsch of 1937 said disdainfully of Heaviside: "*Autodidakt . . . mit einem mystischen Schimmer unwoben . . . eine Literatur die durchweg mathematisch sehr unzulänglich ist.*" How much more fair was Heaviside on Faraday: "That great genius had all sorts of original notions wrong as well as right and, not being a mathematician, could not effectively discriminate." Genius is not exempt from the universal rule that a man who is never wrong will never be superlatively and significantly right!

The physicist, if he is asked to leave Heaviside the mathematician and Heaviside the mathematical physicist to the judgment of his peers, will probably turn to the Kennelly-Heaviside Layer and say, "*Si monumentum requiris circumaudite.*" In his article written in 1902 for the tenth edition of the *Encyclopaedia Britannica,* on "The Theory of Electric Telegraph," Heaviside says, after pointing out that a pair of wires will guide radio waves round a bend if the bend is not sudden:

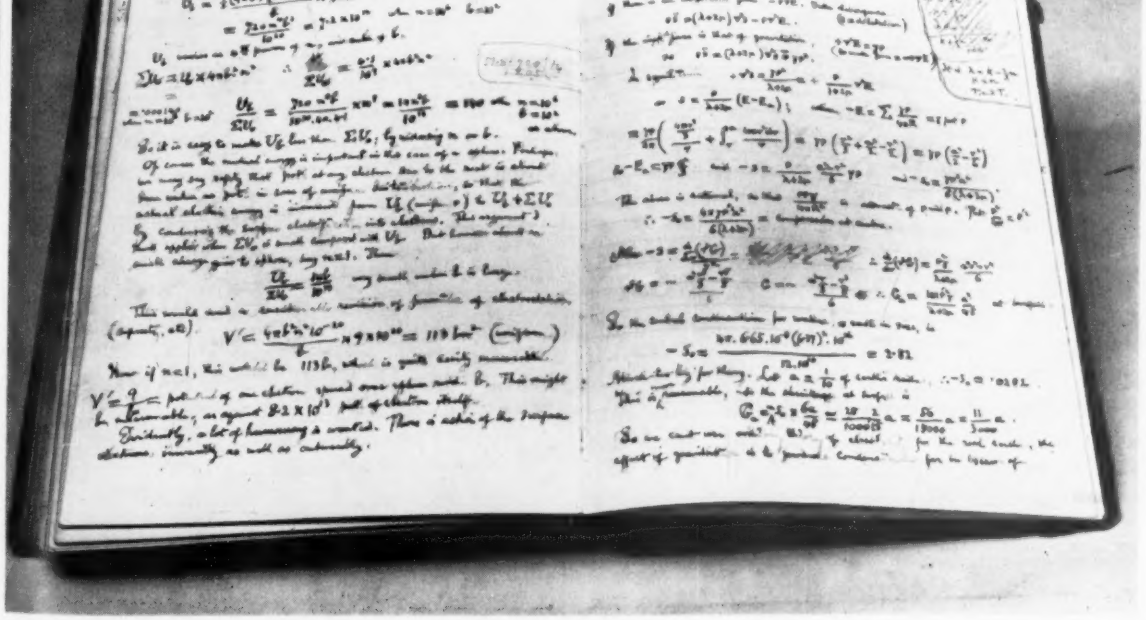
> This guidance is obviously a most important property of wires. There is something similar in "wireless" telegraphy. Sea water, though transparent to light, has quite enough conductivity to make it behave as a conductor for Hertzian waves, and the same is true in a more imperfect manner of the earth. Hence, the waves accommodate themselves to the surface of the sea in the same way as waves follow wires. The irregularities make confusion, no doubt, but the main waves are pulled round by the curvature of the earth, and do not jump off. There is another consideration. There may possibly be a sufficiently conducting layer in the upper air. If so, the waves will, so to speak, catch on to it more or less. Then the guidance will be by the sea on the one side and the upper layer on the other.

Now A. E. Kennelly, born in the then "British

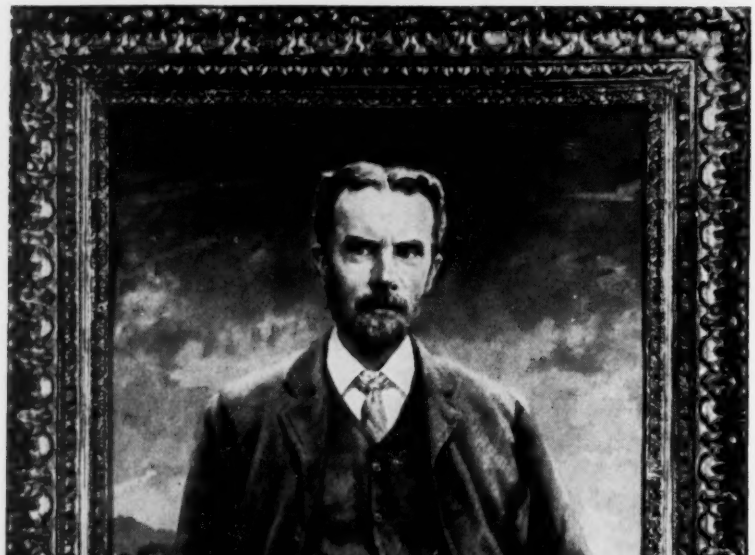
Colony" of Ceylon and subsequently a leader in the sciences of electrical engineering and electrical communications in the United States—and indeed in the world—had independently made a similar suggestion a very few months earlier. In later years, after Appleton and Barnett in Great Britain, and (also independently and a little later) Breit and Tuve in the USA, had measured the height above the earth of the electrically conducting region thus postulated in Britain and America, it bore the happily united name of the Kennelly-Heaviside Layer.

The too-superficial reader may well remember Doetsch when he sees Heaviside's "so to speak, catch on to it more or less," and ask, "What loose talk is this for a mathematician, or whatever he was?" But there is probably no more significant revelation of the precise mind of Heaviside than these apparently loose but in fact indispensable qualifying words. Here the sworn enemy of the pompous, of the "stuffed shirt," of the pontifical, of the authoritarian, is emitting a brilliant idea, capable of close quantitative working-out at a later date, setting out the idea in a context where elaborate mathematical exploration would have been out of place, but already warning us, saying in effect and in few words: "Don't think this is the whole story. Nobody has settled the difficult question of plain diffraction round a sphere, no one has a wholly satisfying picture of this process that I have to call 'catching on, so to speak,' no one yet knows how good a conductor this possible 'conducting layer' I am thinking about must be, nor indeed how good a 'layer' it must be, to help the radio waves to go over the hump; so you must not think that the 'catching-on' process is a 100 percent affair until we can turn 'more-or-less' into mathematical physics." It's so much easier to appear authoritative if one closes the eyes to the subtler gradations between black (whatever that may be) and white (if white isn't an abstraction!). Doubts are feet of clay in a dictator but seven-league boots on a philosopher.

But the engineers are the people who from the beginning—well, *almost* from the beginning—regarded Heaviside as their great benefactor. He talked their kind of language—indeed, he had practiced their art, in cable communications, for a short period in early life, before he learned that, in his hands at least, the pen was mightier than the soldering iron or the telegraph key, that he could do more as an explorer than as a roadmaker. And almost everything that he thought or wrote or did in physics and in mathematics was done in order to advance scientifically the art of electrical communications. Like the best tools of any trade, the



Oliver Heaviside's notebook.



Oliver Heaviside
(from the painting by Francis Hodge).

tools he forged proved invaluable in other trades, but without his zeal for the electric telegraph they might not have been forged, and the communications engineer might have been left to do what little he could with the more refined, more delicate, less versatile tools of the orthodox and rigorous mathematician. His writings were not easy to understand. "That may well be," said Oliver, "but they were much more difficult to write." They were not systematically presented, they bubbled and foamed instead of flowing in a limpid stream. "Those who may prefer a more formally and logically arranged treatment may," said Oliver, "seek it elsewhere and find it if they can; or else go and do it themselves." They repelled the pure mathematicians by their lack of mathematical rigor. That this was so was due to no carelessness on his part, but to deliberate choice. They were roughhewn themselves that they might the more effectively be used, in the hands of comparatively simple-minded pioneers, to hack a way through the then unexplored jungle of electrical communications. They were good for this purpose so long as they contributed to a speedy advance, and did not gravely mislead. It could be left to others to make them more suitable for the fine survey of the territory once it was opened up, but that was necessarily a slower and more specialized job; meanwhile the territory was already yielding rich harvests to the vigorously nonrigorous! "First get on," said Oliver, "in any way possible, and let the logic be left for later work."

So Oliver preached and practiced the doctrine of matching the subtlety to the need, spurning refinements when they seemed to him unnecessary, but through it all showing himself capable of being as rigorous, as subtle, as logical as any when he was convinced of the need. Exuberantly, impatiently, he drove forward, taking his readers into his confidence about the obstacles which everyday life put in the path of progress, gleefully attacking the pretentious, arguing in any mood from warm earnest friendliness through constrained humor to bitter satire, and to ferocious iconoclasm with the truly great and the apparently great. He pointed out serious mistakes made by Lord Kelvin; he corrected errors made by the authoritarian P. G. Tait

in his development of Hamilton's quaternions; he found, of a paper by J. J. Thomson, that "the use of an erroneous boundary condition in the beginning wholly vitiates the subsequent results." He did not, in general, take any wicked pleasure in thus correcting the human errors of the humanly great, but when there was any pretense to more than human infallibility in the incompletely great, or any armor of official complacency worn by the not-so-great risen to high places, then he would sear by the sharp flame of satire, wither by the warm rollicking blast of humor, prick with the fine blade of those "superb powers of mental penetration and intuition." For him there was no supreme authority; no merit in the established order that might not be made the greater by relentless questioning of its validity; no joy in the cool consolidation of gains while there were so many open avenues to the hot pursuit of new knowledge and new understanding.

Himself a very uncommon man, he was not invariably successful in his eager attempts to put his new weapons into the hands of the common man. It was perhaps his closest and most constant friend who wrote thus to him about his mathematical work:

> Some day, when it [*Electromagnetic Theory,* Vols. I–III] becomes a classic, someone will go through it and put it in such a form that people can begin at the beginning and go onwards by steps. You will laugh at all this, but though you must do your mathematics in your own way, I have always felt it a pity that that way has not been more merciful to the beginner. Your vectors you made clear and easy, and the consequence has been that many have appreciated and used them.

It was, indeed, by his lucid enthusiasm for the use of vector algebra in electrical engineering that he most helped that infant prodigy of his age. The great American mathematical physicist Willard Gibbs did more than anyone else to lay the foundations of the vector method; Heaviside made the method widely known and made it attractive to the working engineer. No discussion of Heaviside can be adequate without the realization of two things. One is that his self-educated genius developed his ideas and methods almost wholly independently of the work of others, and in ignorance of much that had already been done in the same field by others. The second is that, as is the way of genius, he was much ahead of his time in the application of his work. How far ahead, in the workaday world, may be judged by a quotation from the very enlightened journal that published much of his work. Heaviside was already within seven years of starting work as a telegraph operator when the *Electrician* published (late in 1861) an editorial which said:

> We may remark that of late years the [experimental] facilities for obtaining definite ideas on the subject of electrical phenomena have greatly increased. Sciences generally become simplified as they advance, albeit in some branches they may attenuate into the abstruse. In electricity there is seldom any need of mathematical or other abstractions; and although the use of formulae may in some instances be a convenience, they may for all practical purposes be dispensed with.

Heaviside met the need that was thus unrecognized, and he met it well before it became acute. His suggestion about the upper conducting layer was made two years before Marconi sent across the Atlantic the waves that, so to speak, caught on, more or less, to the still-hypothetical layer, and thus tightened the bonds between the continents of Henry and Heaviside, of Morse and Heaviside, of Willard Gibbs and Heaviside, of Kennelly and Heaviside, of Heaviside and Pupin, of Heaviside and Carson.

His development of vectors for electrical engineers came at a time when a distinguished authority was writing: "I have elsewhere strongly disapproved of the action of the Board of Trade in allowing electricity in alternating currents to be distributed on a large scale publicly." Without the vector algebra to help progress, the disapproval might have been better founded and justified.

His greatest direct contribution to telegraphy and telephony was his working out of the theory and principles of the inductive loading of communication cables, to reduce the distortions that prevented high-speed telegraphy signaling and long-distance telephoning. His ideas were put into practice by Michael Pupin in the United States some years later, and telegraph and telephone cables were "loaded" with coils of wire wound round an iron core, many such coils being sealed in an iron case, and the cases were housed in manholes at approximately one-mile intervals along the cable. Still later, Heaviside's vision of a continuously loaded cable, in which the iron which was essential for electrical "loading" was wrapped as a close sheaf of wires round the conductors in the cables, materialized.

He developed his first satisfactory stages in the theory of the coaxial cables, which are now used in modern multichannel telephone cables, and in particular in the distribution by cable of programs for radio broadcasting and television.

When it was necessary he suggested or invented words to label important electrical properties, and it is hardly an exaggeration to say that every schoolboy now uses Heaviside words like "resistivity,"

"conductance," "inductance," and "impedance" when he talks of radio circuits.

The Institution of Electrical Engineers celebrated the centenary of Oliver Heaviside's birth by meeting in London on May 18, 1950. There were delivered addresses on the many facets of Heaviside's work. How heavily, and with only general rather than particular acknowledgment, the writer of this brief summary has drawn on the papers there presented will become fully apparent only on the publication by the Institution of its "Heaviside Centenary Volume" before the end of this centenary year. Among the most fascinating of the communications was that of Mr. H. J. Josephs on "Some Unpublished Notes of Oliver Heaviside," these being material on which he had worked toward a fourth volume of his magnum opus *Electromagnetic Theory*. The material was contained in manuscript notes that were only discovered in 1949.

Heaviside was reluctant to accept honors. He accepted election as a Fellow of the Royal Society of London, but he appears to have refused in 1904 to accept the award of its Hughes Medal. He thus denied to later recipients of that high honor the added satisfaction of being companions of Heaviside. He accepted honorary membership in the Institution of Electrical Engineers of Great Britain and America, and the first award of the Faraday Medal of the former.

And the citation for his Ph.D. *honoris causa* from Göttingen forms also a not unworthy epitaph:

That Eminent Man
Oliver Heaviside
An Englishman by Nation, Dwelling at
Newton Abbot
Learned in the Artifices of Analysis
Investigator of the Corpuscles
Which are Wont to be called Electrons
Persevering, Fertile, Happy though
Given to a Solitary Life
Nevertheless among the Propagators of the
Maxwellian Science
Easily the First

GEOMETRICIANS

Pictorial of their austere knowledge,
Their heads seem chiseled by design,
And formulae imponderable
Incline together next to mine.
Could it have been by accident
These profiles sculptured clean as stone,
The angles of the nose and chin,
The perfect curve of skull from bone,
Or years of strict hypotheses
That grayed the tone of skin and hair
All one with space, and trimmed the beards—
Triangles upside-down in air!

ISABELLE BRYANS LONGFELLOW

Fifty Years of Zoology

RICHARD GOLDSCHMIDT

Following a long and distinguished scientific career in Germany, culminating in the directorship of the Kaiser Wilhelm Institut in Berlin from 1921 to 1936, Dr. Goldschmidt is now as firmly established as an American scientist at the University of California in Berkeley. His reputation in zoology, and specifically in genetics, is such as to call for no further introduction of his article.

VIEWED against the background of human history or, for that matter, the history of physics, the progress of zoology in the first half of the twentieth century, great as it is, appears rather unexciting. These fifty years have brought us two world wars and a series of minor ones (minor only to the outsiders.) They have seen large empires toppling and new ones established; they have seen the almost complete disappearance of royalty, the end of colonial imperialism, and the upsurge of formerly dependent nations. They have seen the victory in considerable parts of the world of the extreme form of Marxian theory and the steady increase of moderate socialism outside that orbit; they have seen the disappearance of spatial separation on the globe, together with the increase of the power of destruction—One World, for good or bad; they have seen the worst incarnation of evil in the world's history and the first toddling steps toward unification of mankind.

In the field of science it is physics that occupies the front of the stage in an unbelievable series of major discoveries: the quantum theory, with all its revolutionary consequences; insight into the structure of the atom with its elementary particles; the transformation of elements and the disappearance of barriers between chemistry and physics with the wonderful orderliness of the periodical system; the analysis of the organization of matter by X-ray spectroscopy; experimental radioactivity and the nature of isotopes; the splitting of the atomic nucleus; and, connecting all, quantum mechanics and relativity. Indeed, the zoologist has nothing equally spectacular to report.

Although less spectacular and appealing to the outsider, the work of zoologists in these fifty years has meant as much progress in the understanding of the organism as the work of physicists in the understanding of matter. Also, in zoology completely new disciplines have emerged and have been built up to an admirable structure. If we try to review some of this we must realize that completeness is not possible in the space available, aside from the impossibility of mastering all fields equally. Thus I have to apologize from the beginning for eventual omissions and also for evaluations that might not be agreed upon by everybody.*

At the very beginning of the century one of the big International Congresses of Zoology was held in Berlin, in 1901. The proceedings may serve, to a certain degree, as a measure of the condition of zoology fifty years ago. They may, by the way, also serve as a measure of the condition of zoologists at that time. Having attended the congress as a graduate student, I remember that in all the four general sessions, for which the entire Reichstagsbuilding was reserved, all participants were required to appear in tails and white ties. The material side of the congress was considered so important that in the printed proceedings the menu of one of the innumerable free banquets is recited with its sequence of a dozen delicacies, each accompanied by the proper wine. It reads today like a medieval document.

Looking over the proceedings, we find indeed a zoology very different from that of today. Great importance was attached to what Driesch had called the philosophy of the organism. Driesch himself produced his so-called experimental proofs for vitalism, based upon the assumption that the mechanists must consider the organism as a machine, and then showing that a machine cannot do what the organism can do. Wilhelm Roux objected meekly that a physicochemical system can do what a machine cannot. But here, in the section on ex-

* It is clearly not possible to mention individually the thousands of fine zoologists whose work characterizes the period; therefore, only the names of such men have been included who, in the author's opinion, pioneered new fields, though others may have done as much or more in building them up. There are some fields in which it is impossible to name individual innovators, because they progressed on a broad front, through the work of many.

perimental zoology, the vitalists were very powerful, Driesch, Herbst, Spemann, Uxküll all being supporters of this doctrine. Actually, many of the younger zoologists who were in ideological opposition to the old, purely descriptive zoology toyed with vitalism. Thus one can understand why the congress invited one of the greatest zoologists, Otto Bütschli, to give one of the main addresses on "Mechanism and Vitalism." Bütschli, as much at home in physics, chemistry, and philosophy as in zoology, demolished the arguments of the vitalists. It is interesting to see how interest in this basic philosophical problem of zoology has since been relegated to the background under the impact of physicochemical study of the organism. After the peak was reached with Driesch's *Philosophy of the Organism,* fewer and fewer active zoologists took part in these discussions, which practically disappeared from zoological literature, Max Hartmann (himself no vitalist) being one of the few exceptions. Radl's historical book signifies more or less the end of this period, though the cofounder of neovitalism and discoverer of lens-regeneration in amphibia, G. Wolff, published his vitalistic credo as late as the thirties. The vitalistic dogma lingered on for a long time in various disguises, as emergent evolution (Lloyd Morgan), psycho-Lamarckism (Pauly), the Mneme (Semon), and especially as holism (Smuts), which, in Germany under the Nazis, had a kind of official sanction on the basis of a childish parallelization of totalitarian and holistic ideas. Today few zoologists are tempted to speculate on these problems which, strangest of all spectacles, are beginning to move into the realm of the natural mechanists, the theoretical physicists (Jordan, Schroedinger, Bohr).

The basis of all zoology was and is taxonomy, the study of the diversity of animal form. Nobody would expect revolutionary changes in this field within fifty years. But actually a very healthy and far-reaching evolution has taken place. Innumerable new species have of course been described, and there has been the usual squabble about nomenclature, which occupied much time in the congress of 1901 and was still far too much alive in the International Congress of 1948. Even brand-new conspicuous animals have been added to the popular list. Just as the century opened, the first news came from Africa of the okapi, an antediluvian relic, living specimens of which one can now admire in zoological gardens. The same is true for the dwarf hippopotamus and the giant Komodo lizards, and rather recently a real living fossil, the crossopterygian *Latimeria,* was found. At the other end of the size scale an entire new order was discovered, the Myrientomata, located somewhere between myriopods and insects. But, in general, the stream of surprising and strange new forms brought home from the deep-sea expeditions of the nineteenth century began to ebb, though some of the finest work on deep-sea animals (Brauer, Reagan) appeared in this century. Such brilliantly illustrated monographs as Brauer's *Deep Sea Fishes* have gone out of fashion (also funds), and the beautiful volumes of the *Fauna and Flora of the Gulf of Naples* have slowly ceased to appear. The marine zoological stations, which increased in number and size, more or less changed their program to experimental work in embryology, ecology, oceanography, and comparative physiology and became as much institutions of teaching as of research. I think that the exhibit of large numbers of the delightful and aesthetically perfect glass sponges from the depths of Sagami Bay, which Ijima exhibited in Berlin in 1901, was the last show of its kind at a major gathering, appealing alike to the artistic sense and to the thoughts of the naturalist.

The really important development of taxonomy in the past fifty years does not concern new animals but the general emphasis on taxonomic work. Since Darwin's time taxonomy had tried to link itself cosely to evolution, and there was no major taxonomic work that did not try to link the cataloguing of species with geographical distribution and, in the end, with speculations on the phylogeny and evolution of the respective groups. Near the end of the last century the first steps were taken toward what has been termed recently, rather inappropriately, the "new systematics." Taxonomists directed their attention to the smallest taxonomic units, the subspecies, and found the species represented by an array of geographically (or ecologically) separated, interfertile subspecies. Thus Kleinschmidt, a preacher and amateur ornithologist, developed the *Rassenkreis* concept of the species (not without a theological afterthought).

Soon Hartert, the ornithologist, Jordan, the lepidopterologist, Matchie, the mammalogist, and Heincke and Hofer, the ichthyologists, followed in their own way. At the congress in 1901 the new ideas were not represented. I remember well how Matchie, the secretary general of this congress, was considered a kind of comic figure, because he claimed that he could distinguish and name with a trinary nomenclature lions or giraffes from different, even small, parts of their African habitat. During the first decades of the century the *Rassenkreis* concept of animal taxonomy conquered the field, the protagonist in our country being our late Joseph Grinnell, in Europe, Rensch. Taxonomy thus be-

came closely linked to ecology, geography, paleontology, and climatology. The simultaneous rise of genetics resulted in the establishment of a link with that field, when geneticists with knowledge of the developments in taxonomy, started to attack experimentally the combined problems in such animals as *Peromyscus* and *Lymantria* (Sumner, Goldschmidt). Such studies brought the facts of taxonomy into line with the genetical analysis of evolution, and taxonomists today try to assemble all information on the species they are studying, including ecology, intersterility or -fertility, adaptation, isolation, and size of populations, in the belief (sometimes rather sanguine in view of the nature of the material) that they are actually studying evolution. Taxonomy thus strives to take its well-established place in modern biology.

The zoological fields that had made greatest progress in the nineteenth century were morphology, including comparative anatomy, and descriptive embryology. One could hardly expect great revolutionary changes in these fields. But there was still much room for factual work, and the past fifty years have brought a constant stream of new data, together with some splendid survey books like those of Bütschli, Versluys *et al.*, and Romer. Most of the genuine progress was made by integration with neighboring disciplines. Comparative anatomy made its greatest strides by incorporating paleontological material (Osborn, Watson, Stromer, Broili, and Romer), and in close connection with embryology. New insight into the anatomy of the oldest vertebrates gained by the unexpected possibility of elucidating their internal structure (Stensiö), and new material on the reptilian precursors of mammals allowed the comparative anatomists to fill the gaps in their material and to develop a more comprehensive picture of vertebrate morphology and relationships (Simpson). But also in straight comparative anatomy much material was added to the classic store, the name of Severtzoff being outstanding in this work. As the zoologist has to include man also in the material of his study, it might be appropriate to mention that in the 1901 congress an anthropologist gave one of the main papers, on fossil man, in which he climaxed his analysis with the conclusion that *Pithecanthropus* was a hybrid between a Neanderthal man and an ape. It suffices to mention the names of Dubois, Keith, Weidenreich, von Königswald, Dart, and Broom to show the distance traveled in this field since 1901.

Also in other fields of pure morphology many a basic contribution to our knowledge has been made. I might mention the thorough exploration of the nephridia of lower organisms, with their solenocytes, reaching up to the Acrania (Goodrich, Boveri); or the still-progressing insight into the finer structure of the nervous system all over the animal kingdom (Apathy, Bethe), the discovery of cell-constant animals, like nematodes (Goldschmidt, Martini), or the still-inconclusive work on Mesozoa (Caullery, Hartmann, Neresheimer). Perhaps the most fascinating chapter is the discovery and description (Sulč, Pierantoni, Buchner) of the unbelievable variety of organs in insects containing symbiotic fungi and yeasts needed as sources of vitamins, and the amazing methods of securing their transmission to the offspring (Buchner). Again major progress has been made by combining morphological study with the analysis of function. Just as work in comparative physiology contains much morphological data, the study of pure morphology has been stimulated by interest in function. The morphology of kidney or brain is a suitable example. Even today the physiologist or ecologist or geneticist who needs specific morphological information will meet numerous gaps in our knowledge of structure. One of the typical features of the past period of descriptive zoology was the compilation of huge repertories in many volumes like the *Cambridge Natural History* and Kükenthal's handbook; a new French one has just started publication.

The really revolutionary developments in zoology are, of course, those linked to completely new fields of knowledge. But some of the older fields have also advanced by such leaps and bounds that their progress in the past fifty years may be termed revolutionary. At the congress of 1901 there was only one section in session which today could be termed modern zoology—the section on experimental zoology, actually meaning mostly experimental embryology. It was a small section, assembled around one long table. But here I saw seated on the comfortable chairs of the German Bundesrat Oscar and Richard Hertwig, E. B. Wilson, Wilhelm Roux, Hans Driesch, Curt Herbst, Yves Delage, H. E. Ziegler, E. Rhumbler, and Hans Spemann, each of them a classical figure in experimental embryology. Young Spemann read a paper on his now-classic experiments in separating *Triton* blastomeres, and taciturn, critical O. Hertwig congratulated him in extravagant terms. The American pioneers of experimental embryology, Conklin, Harrison, Lillie, and Morgan, happened to be absent. The greatest experimenter of the first decade, Boveri, also was not present. Much of the work at that time dealt with mosaic or nonmosaic development, prospective potencies, harmonic equipotential systems, and the laws of regeneration (Child, Herbst, Peebles, Korschelt). Fifteen years

later Spemann discovered the so-called organizer and started a new period of experimental embryology, the leadership of which he shared with R. G. Harrison. The new discoveries brought about a wave of experimental work with both vertebrate and invertebrate embryos, using new methods. Important contributions were made for echinoderms (von Ubisch, Hörstadius), insects (Seidel), and other organisms. The central problem, the determination of pattern, was the subject of extensive work. Discoveries that I consider as especially appealing to the imagination are the analysis of the determination of the amphibian eye (Wolff, Spemann), of the amphibian appendages (Harrison), of the feather structure and pigment in birds (Lillie, Willier) and of the pattern of the lepidopteran wing (Kühn, Henke). One of the thought-provoking developments was Child's lifework on metabolic gradients, and the field concept in embryology (Gurwitsch, Weiss, Guyénot) suggested new levels of understanding. Experimental embryology has led to far-reaching results, and its work is not yet ended. A new and fruitful discipline has more recently been added, the application of biochemistry to the problems of embryological determination (Holtfreter, Needham, Brachet, Runnström), to which, I suppose, the next half-century's work in this field will belong. The study of the physiology of fertilization, initiated by Loeb and Lillie, has likewise entered its chemical phase now (Runnström, Hartmann, Tyler) and may also be considered here.

The brilliant upsurge of experimental embryology completely overshadowed descriptive embryology, which could no longer reach such attainments as those of Kowalevsky, Metschnikoff, and Hatschek. But in a more limited field such work as that on the vertebrate head (Neal, Severtzoff, Koltzoff) and that on early development and cell lineage in invertebrates (Whitman, Wilson, Lillie, Conklin), or on the metamorphosis of invertebrates (McBride, Woltereck) secured definite and important advances in our understanding of development. Much of this descriptive work was of course done with the help of experimental methods.

One more facet of experimental embryology in a wider sense should be mentioned, the modern study of growth. It received much impetus from the introduction of mathematical methods (D'Arcy Thompson) and physicochemical points of view (Crozier), but moved largely out of the realm of zoological study when vitamins and growth hormones were discovered. Today the biochemist and the biophysicist are supreme in this field of study. The most appealing aspect of the growth problem to the zoologist has become the successful study of heterogonic growth (Julian Huxley), a field which is of importance to comparative anatomy, embryology, genetics, evolution, and paleontology.

The end of the nineteenth century had seen the establishment of protozoology as a science. Having been an important and interesting part of zoology under the leadership of Bütschli, R. Hertwig, and Maupas, it had finally attracted wider attention when it became apparent that major pathogenic organisms belonged to this group of animals. (Laveran's discovery of the malaria parasite had been the turning point.) At this time, just the end of the nineteenth century, a very young zoologist, Fritz Schaudinn, had found some amazingly complicated life cycles in Rhizopods and Sporozoa, which involved both asexual and sexual phases. This led indirectly to the discovery of the life cycle of the malaria parasite by pointing to the stages and cycle to be expected. Ross had proved the transmission by mosquitoes, but it was the zoologist Grassi who could denounce the real culprit, *Anopheles,* and who first worked out the cycle with the details required by the protozoologist. At the congress of 1901 his was one of the major addresses. From this start protozoology developed into a great science, partly in consequence of its importance for medicine, which increased steadily with the discovery of new pathogenic forms and their overwhelming significance for life and agriculture in the tropics. But fundamental protozoology also made great advances through the utilization of protozoa as materials for cytological research (R. Hertwig, Léger), covering mitosis and meiosis, the so-called neuromotor system (Klein, Kofoid), centrioles, and often-complicated cytoplasmic structures and life cycles (Kofoid, Hartmann, Doflein, Jollos, Belar, Fauré-Frémiet, Chatton). Protozoa were much used for studies in elementary physiology following up the early work of Kühne and Verworn, and in animal behavior (Jennings). A major discovery was the proof that some protozoa follow the plant type of meiosis and haploid-diploid cycle (Dobell). The present trend toward biochemical exploration has again turned to protozoa as a suitable material (Lwoff, Kidder), and within the last years (initiated by Jennings), protozoa have become promising tools of genetic research, which has also led to unexpected insight into such old problems of protozoology as sexuality (Hartmann and school, Sonneborn), parthenogenesis (Erdmann-Woodruff), function of the macronucleus, and meaning of conjugation in infusoria (Sonneborn).

A field that has been studied as long as there has been a zoological science is what used to be called

natural history, or biology of animals, and is now called ecology. This was the domain of the naturalists proper, who accumulated an immense quantity of material, much of which was described in a way never since surpassed. Only at the end of the last century this field entered what we may call the higher level of study, when quantitative and physiocochemical methods of experimentation were added to observation and simple experimentation. It was mainly the rise of interest in plankton organisms that started the modernization of this field (Hensen), and contact with problems of applied zoology and oceanography considerably stimulated the development of ecology (Hensen, Hjorth, Hofer). During the past half-century ecology has developed into an experimental science so closely akin to comparative physiology that it can hardly be separated from it. Conspicuous on the one hand is the development of marine ecology in close contact with oceanography. Problems of marine plankton and of the ecology of littoral and intertidal animals were studied with the help of all quantitative methods (Hjorth, Yonge). Animal associations, communities, successions (Dahl, Sheldon, Elton), and interrelations were followed. Another development, almost completely of the past fifty years, is the study of fresh-water biology in its manifold interrelations with physical and chemical factors of the environment, as well as with plant life. The work of innumerable laboratories of fresh-water biology, most of them started in this century, bears witness to the importance of this field (Forel, Lauterborn, Woltereck, Thienemann, Kofoid). Also the ecology of terrestrial animals, from worms to mammals, was studied more and more, with a considerable share of interest created by applied entomology (Uvarov) and the study of social insects (Forel, Wasmann, Wheeler, Santchi). Ecology of populations became an interesting field of study following Pearl's pioneer work. The general field of physical and chemical factors in the environment acting upon the organism was the subject of innumerable papers, with much entomological work (Bachmetjeff) and work on lower water-living organisms (Semper, Hesse). In the last decades its importance was considerably enhanced when adaptation to ecological niches became one of the important facets in the study of evolution and selection. Thus ecology touches at the end of its recent development upon numerous important fields of fundamental and applied zoology, as well as upon taxonomy, genetics, evolution, physiology, animal psychology, and physical geography. The recent books which summarize this field (Elton, Hesse-Allee, Allee *et al.*) bear witness to the huge amount of material accumulated in the last decades on foundations built by the pioneers of the nineteenth century (Semper, Davenport). At this point comparative physiology should be mentioned, though much of it is straight physiology. But in the hands of many able zoologists (e.g., Jordan, von Buddenbrock, Harvey, Pantin) the pure physiological work became well integrated with the facts and problems of zoology.

Animal psychology and behavior have just been mentioned. At the end of the last century a reaction against the anthropomorphic type of discussion had set in, and under the leadership of physiologists the pendulum swung to the other extreme: Bethe, Beer, and Uxküll coined the phrase "reflex-automatons" and demanded that all interpretations in psychological terms disappear. Loeb's theory of tropisms amounted to a similar point of view. But under the leadership of H. J. Jennings opposition to these purely mechanistic views was being voiced and the experimental study of behavior in the lowest organisms inaugurated. Much of the discussion of fifty years ago centered around the instincts of the social insects, and it is not without significance that one of the main addresses at the 1901 congress was given by the psychiatrist and ant specialist Forel, on the psychic abilities of ants. The animated discussions between Forel, Pater Wasmann, S.J., and Bethe, were a big feature of zoological literature, and much important work has been done since (Wheeler, Emerson, Light). The past fifty years have brought many changes in studies in this field apart from those studies that are considered to be pure ecology (Allee). It was largely taken out of the realms as well of semitheological discussion as of crude simplistic study and turned over to quantitative experimentation. Much of this moved away from the hands of the zoologist and was taken over by the experimental psychologist after Wolfgang Köhler set the standard for the experimental and analytical approach, and the maze and alternative-choice method were introduced as major tools. The ground this science has traversed in these fifty years can be realized if the methods of approach of Romanes, Forel, and Wasmann are compared with the present ones of Lashley, Köhler, and Tolman. In general terms, the trend has returned to the views of the old Darwinians, who looked for an evolution of psychic faculties, seasoned with a sprinkling of Gestalt theory and electrophysiology.

While this shift to psychological experimentation was taking place, the zoologists kept up their share of experimentation in such fields at the borderline of zoology, physiology, and psychology as the study of the sensory functions of the lower animals. Leaving

aside the purely physiological work that may be characterized by the terms synapse, acetylcholine, flicker effect, and visual purple, the greatest progress was made through the use of the training and punishment method so masterfully applied by von Frisch. The results on color sense, hearing, and the methods of communication in bees (and fishes) belong among the landmarks of zoology of the present century. Similarly, the problems relating to the general function of the nervous system, mainly the domain of the physiologist, received much successful attention from zoologists as exemplified in the work on neurohumors (Parker), nervous control of color adaptation (von Frisch, Sumner), and the experiments that led to the resonance theory of Weiss.

Thus far we have reported the far-reaching and important developments of zoology in many fields which pushed knowledge far beyond that of fifty years ago. But only in very few instances, as in experimental embryology, might we call the progress revolutionary. There are some branches of zoology, however, which, after beginnings in the last century, have moved at a revolutionary pace, and others of greatest importance which were created completely in this century.

At the congress of 1901 a single cytological paper was read by E. B. Wilson on artificial parthenogenesis, and there was of course no section on cytology. One of the main addresses, given by Yves Delage, dealt with the theories of fertilization; it reads today like something out of another world (see above). What is called cytology today was completely lacking. Actually, the basis of modern cytology had already been laid by Bütschli, Strasburger, O. Hertwig, Flemming, von Beneden, and Boveri, and the decisive basic facts were clear. But a completely new impetus was needed to allow the revolutionary development of the past five decades. It was furnished by the rise of genetics and biochemistry and biophysics.

Four major subdivisions of cytology share in this epochal rise. The first is cell physiology, which was already a flourishing field of research at the beginning of the century. Its phenomenal development was coincident with the development of physical chemistry and colloid chemistry, which furnished the methods and concepts. Practically everything we know about the constitution of protoplasm, permeability, intake and transport of materials, metabolism, physical properties, movements, surface phenomena, changes of colloidal states, respiratory and other enzymes, is a recent acquisition. Actually, cell physiology has moved outside the field of zoology into the folds of a new science, biochemical and biophysical cytology, which is trying to attack the ultimate problems of what life actually is.

The second part of cytology is concerned with the cell as a factor in development and thus is closely linked with experimental embryology and also with certain aspects of genetics. We may mention the role of centrioles in cell division and fertilization (Boveri), the cytology of parthenogenesis (Brauer, Artom, Vandel, Seiler), and the work on experimental merogony showing the limits of viability of haploid cells in animals (Boveri, Baltzer). The discovery of the nucleoplasmic ratio (Gerassimoff, Boveri, R. Hertwig) has led to important insight into the relation of the component cells to the embryo as a whole. It has led recently to the recognition of endomitosis (Jacoby, Geitler) as a possible major factor in embryonic differentiation. The discovery of the possibility of growing tissue in vitro (R. G. Harrison) has opened new fields of attack on cytological, cytochemical, and pathological problems and on problems of embryonic differentiation. In the hands of Erdmann, A. Fischer, Lewis, and Holtfreter it has become almost a separate science.

A third successful field of cytological advance was the study of cytoplasmic structure and cytoplasmic inclusions, fields which were opened toward the end of the nineteenth century by the work of Bütschli on the colloidal structure of protoplasm and the discovery of mitochondria (Benda) and the Golgi apparatus. Progress in the study of protoplasm, apart from cell-physiological and biophysical aspects, is mainly due to the introduction of colloid chemistry and protein chemistry into the field (e.g., Seifriz) while the role of mitochondria and Golgi material is still incompletely understood in spite of mountains of work, the latter being now under suspicion as an artifact. The importance of interchange of material between nucleus and cytoplasm was early understood (R. Hertwig, Goldschmidt), and the phenomenon is now being studied by biochemical methods (Brachet, Caspersson), which promise new insight into the function of the cell.

The most conspicuous development in cytology in the past fifty years has been due to its intimate association with the rising science of genetics. The chromosomes had been firmly established as the bearers of the determinants of heredity by Weismann, Roux, and Boveri. Early in this century Boveri published his beautiful experiments to prove the nature of the chromosomes as the real hereditary material. But only in connection with genetic experimentation could the final proof of that theory be obtained (Sutton, Morgan, Bridges). Since that time the details of meiotic divisions and chromo-

some structure, already known at the end of the last century (Boveri, Rückert) have become of supreme importance. The discoveries are too many to recount, and the contribution of botanists must be added to those of the zoologists. Some of the landmarks are the analysis of the meiotic prophase (de Winiwarter), the establishment of the standard mode of meiosis (Rückert, K. and E. Schreiner, Montgomery, Gelei), the discovery of chiasmata (Janssens), the detailed analysis of chiasmata (Darlington), the role of the centromere (Darlington, Schrader), the distinction of euchromatin and heterochromatin (Heitz), the introduction of the salivary-gland chromosomes as cytogenetic tools (Heitz and Bauer, Painter), the discovery of the role of polyploidy (Winkler, Sakamura), the analysis of chromosomal behavior in hybrids (Rosenberg, Federley, Winge), and in structural hybrids (Belling, Darlington, Cleland). In all this and much other work the boundaries between zoology and botany had broken down, just as was the case in genetics. Finally all this work led into the quest for the biochemical nature of chromosomes and its relation to their function in heredity, a field which—early envisaged by Koltzoff—is now in the foreground of genetics, cytology, and biochemistry (with Caspersson pioneering).

One of the most successful chapters in the recent development of cytology in conjunction with genetics is the discovery of the chromosomal basis of sex determination. Toward the end of the last century Henking had found chromosomes of specific behavior, the so-called accessory chromosomes. Early in this century McClung proposed the idea that here the mechanism for the production of the two sexes in equal numbers was visible, and E. B. Wilson produced overwhelming cytological evidence and the correct interpretation. Major steps made since include Seiler's demonstration of the WZ-chromosomes in female heterogamety, Morgan's analysis of the strange features of the chromosomal cycle in *Phylloxera,* the remarkable behavior of the sex chromosomes and autosomes in *Sciara* (Metz), and the cytogenetic work on the X and Y chromosomes of *Drosophila* by Bridges and Stern. The establishment of the distinction between intersexuality and gynandromorphism (Goldschmidt) and the analysis of gynandromorphism (Boveri, Morgan, Toyama) belong here, though only in one single case have both genetics and cytology been explored (Goldschmidt-Katsuki).

It is interesting to see that the problem of sex determination was also represented in the congress of 1901 and how it was treated. A Viennese obstetrician, Schenk, had claimed that he could control sex in man by a diet for pregnant women which was supposed to control the lecithin content of the egg. In view of the immense publicity given to "the Schenk theory," he was asked to present his material to the congress, and his paper with the ensuing discussion takes up an unusually large space in the proceedings. If we read it today we are shocked by the level of the paper and its discussion, and simultaneously amazed at the progress in the solution of this problem which the following two decades were to bring.

This brings us to the other great field that developed completely after 1900 out of practically nothing into a revolutionary science—genetics, which again is common to zoology and botany, and today also to bacteriology and virology. The relative share that zoologists had in the development of this science, though it was first introduced by the botanists, is of such magnitude that we feel entitled to include genetics in the recent surge of zoology. In these fifty years genetics has grown into a science of such dimensions that an unfinished handbook of about fifteen years ago contemplated a dozen big volumes. Genetics sends its branches into all fields of zoology, taxonomy and morphology, embryology and cytology, ecology, and so forth. Thus it may suffice to enumerate only the main chapters and problems, as far as they can be attacked from the zoological side.

Classic genetics deals first with Mendelian inheritance, and the different kinds of interplay between mendelizing genes, which the first zoological geneticists analyzed (Bateson, Punnett, Doncaster, Cuénot, Toyama, Castle, Lang, Davenport), are still basic to the study of genetics. The expansion of Mendelism to somewhat more complicated cases like multiple-factor and polyallelic inheritance was primarily accomplished by botanists, though much was anticipated by Cuénot. Actually, in spite of the considerable share of the zoologists in the early development of genetics, zoology as a whole remained reluctant for a long time to acknowledge the merits of genetics. It is a sort of historical joke that T. H. Morgan argued at that time against the purity of the gametes and ridiculed multiple-factor inheritance. But since 1910 genetic experimentation has been dominated by the bulk of the work done with Drosophila, and the share of zoologists in important discoveries has steadily increased. The following chapters have been more or less in the center of progress if we leave out completely problems confined to plants, such as structural hybridity and allotetraploidy: The mapping of chromosomes by crossover analysis has held the center of the stage

for a long time; with its extension to the study of chromosomal abnormalities it has made possible exhaustive description of the mechanism of transmission of the chromosomal units, the genes (Morgan, Sturtevant, Muller, Bridges), successfully confirmed by the cytogenetic proof of crossing over by Stern and McClintock-Creighton, thus establishing the classical theory of the gene. These studies simplified the problem of the mechanics of hereditary transmission so that the quintessence of Mendelian heredity may be stated in a few words: the statics of transmission of hereditary traits is a consequence and corollary of the normal of abnormal maneuvers of the chromosomes and their parts in sex cells, and, eventually, somatic cells.

One of the lines of work in which zoologists have led is the genetics of sex determination. In the earliest days of genetics Doncaster and Bateson realized that the production of the two sexes in equal numbers in the normal case must be based upon a genetic situation comparable to a Mendelian backcross (Mendel himself had hinted at this, and Correns later performed the first experiment with plants). The discovery of the sex chromosomes proved the essential correctness of this view. But it was almost ten years before the underlying genetic situation could be analyzed through the discovery of the phenomenon of intersexuality and its explanation by the balance theory of sex factors (Goldschmidt). One of the direct consequences of this was the idea that gene-controlled reactions work in a balanced, attuned way (Goldschmidt)—consequently termed the theory of genic balance. Speaking only of the genetical aspect of the sex problem, innumerable new facts have been added, the most important ones by Witschi, Standfuss, Bridges, and Seiler. Cases have been found in hymenoptera (Whiting) and fishes (Winge, Aida, Kosswig), which seem to have an unusual genetic basis. To do justice to all the facts of genetics of sex, which were unknown fifty years ago, a considerable volume would have to be written.

Another important field of genetics, almost completely in the hands of zoologists, is the study of the action of genetic determiners in controlling development, sometimes called phenogenetics or physiological genetics. The facts of animal development and the results and methods of experimental embryology permitted a first approach to the problem. The study of the development of mutants as compared with the original form (Häcker), the production of nonhereditary copies of mutants (phenocopies) by external agencies (Goldschmidt), the study of the effects of environmental changes upon the development and the phenotype of mutants (Zeleny), the study of reactions and interactions of different mutants controlling the same organs, the study of effects of different dosages of mutant loci (Muller, Stern), the study of sensitive periods in development (Zeleny, Kühn)—all these led to information upon the main lines of developmental control by the genetic material which could be expressed in terms of integrated speeds and rates, reaction velocities, and threshold effects in the interplay of gene-controlled reactions which steer development (Goldschmidt, S. Wright). Following some earlier leads, the control of the synthesis of chemical end products by Mendelian genes has recently been studied, and the genetic control of definite, chemically known steps—e.g., in the synthesis of eye pigment—has been elucidated by brilliant experimental methods (Kühn-Caspari, Beadle, Ephrussi) after a first successful attack on the biochemical genetics of alcaptonuria in man (Garrod). (The work on flower colors and nutritional chemistry in fungi belongs to plant genetics.)

As we have already discussed the rise of cytology, the area of overlap between cytology and genetics, called cytogenetics, should be mentioned but briefly. The zoologists Boveri and Sutton first realized the identity of chromosomal and Mendelian behavior, and Federley first described the chromosomal behavior of species hybrids, which is at the base of a large field of investigation most fruitful in the study of genetics and evolution in plants. Otherwise, the intimate details of cytogenetics, segmental interchange, trisomics and monosomics, auto- and allopolyploidy, belong for the most part in the domain of plant genetics. But in one field of cytogenetics animal material is predominant: the study, both genetical and cytological, of the chromosomal set and its composition in different species of the same genus. The work done with Drosophila species is here the most successful (Metz, Sturtevant). We have mentioned above the discovery of the salivary gland chromosomes of Diptera. They have become a major tool of cytogenetics, indispensable to the Drosophila geneticists and a real triumph for the chromosome theory of heredity (Painter, Bridges). At present they also offer an important material for the chemical study of chromosomes (Caspersson-Schultz).

At the base of all genetic work is the study of the process of mutation. Since the discovery that the rate of mutation can be greatly accelerated by irradiating the chromosomes with X-rays and other radiations (Muller), as well as temperature shocks (Muller, Goldschmidt, Timofeeff) and chemicals (Auerbach), experimental mutation has been one of the important tools in the analysis of the basic

concept of genetics, the theory of the gene. Again the work done with Drosophila is in the first line of this attack, a major accomplishment being the discovery of the linear relationship between dosage of radiation and mutation rate (Oliver, Hanson, Stadler). A science of radiation genetics has since been developed as a subfield of genetics. Finally, the genetic work with Infusoria (now also with bacteria and viruses) initiated in the early days of Mendelism by Jennings, and brilliantly built up by Sonneborn, begins to link genetics with biochemistry and immunochemistry while simultaneously focusing attention on the still doubtful role of cytoplasm in heredity, including the phenomenon of Dauermodification (Jollos). Recently, immunochemistry has also entered into genetic research with higher animals (Irwin). All this work comes into consideration when the ultimate problem is attacked—the question of the nature of the gene. The facts of chromosomal breakage by radiation and the remarkable position effect (Sturtevant) bid fair to open new concepts beyond the range of the classical theory of the gene (Muller, Goldschmidt).

It is from genetics that the study of evolution has received new impetus. We have reported already upon the combined taxonomic and genetic work on basic problems of evolution. The introduction of statistical methods into the study of populations of animals (Punnett, Hardy, Weinberg), in which animal geneticists had a decisive share (Haldane, Wright, Fisher), furnished the tool for a new evaluation and a quantitative experimental attack upon the problems of competition, selection, distribution of mutants and their fluctuation, isolation, and ecological adaptation in natural populations of animals (Wright, Dobzhansky). These studies are at their height at present, and the future will show whether they can lead to a real understanding of evolution beyond the level of the lowest categories. Some zoologists and paleontologists doubt it (Goldschmidt, Schindewolf).

It is not necessary to treat the progress in the study of evolution in detail, as we have met with it on many occasions. But a few facts and ideas may be assembled which characterize the work of the past fifty years. The ideas of preadaptation and immigration into the ecological niche (Cuénot, Davenport) and the consequent conception of the ecotype (Turesson) have become basic tenets. The role of selection has become even more firmly established and understood on the basis of the facts of mutation and the details of distribution and recombination of mutant loci in interbreeding populations (so-called transfer of genes, or gene flow). Details of genetical knowledge like linkage, lethal factors, balanced lethals, translocations, and inversions enter this picture. Genetic and chromosomal stability plays a role in the origin of genetic isolation. The most important discovery in this field is probably the definition of genetic drift (the Hagedoorns, Sewall Wright, Dubinin), which shows that in populations of small size mutants may accumulate (and drift in either direction) without selective advantage, even with negative selective value. Mutation and selection pressure have become household words, and they can be defined mathematically for different breeding systems. Examples in nature illustrating these principles have been studied, including industrial melanism (Harrison, Goldschmidt, Ford), and distribution of inversions of adaptive value in Drosophila populations (Dobzhansky, Sturtevant). The already quoted work on the genetics of subspecific geographic clines (Sumner and Goldschmidt), and the purely taxonomic work meant to show that subspecies are "incipient species" (Darwin), belong here. Much of the latter work is on insular faunas (Stresemann, Mayr, Murphy). In a wider field a better knowledge of mimicry and mimetism (Poulton, Süffert, Carpenter, Cott) has put the important facts upon a solid experimental basis. The facts are still unfavorable to the neo-Darwinian point of view. The study of growth, especially heterogonic growth, and the experimental work on potentialities of development contain a wealth of facts with great bearing on evolutionary thought, which will still have to come into their own. The share of paleontology in elucidating evolution has increased considerably and will continue to do so (Stromer, Simpson, Schindewolf, Dacqué). Finally, immunochemistry has entered the field in attempts to elucidate phylogenetic relationships by serological reactions (Nuttall, Boyden). The problem of phylogeny has also been treated interestingly from the methodological point of view (Tschulok, Naef).

There is another field of zoology which belongs almost completely to this century, the study of the hormones. Certainly much work in this field has been done by nonzoologists, physiologists, and biochemists. But many of the basic discoveries that led later to the physiological, biochemical, and pathological work were made by zoologists. Here we mention only those aspects of the science of endocrinology that may be properly included in general zoology. Zoologists were early interested in the study of sex hormones because of their importance for the problem of sex determination, as well as for morphogenetic features like secondary sex characters. The method of castration and transplanta-

tion as a means of studying the sex hormones had been used as early as 1849 by Berthold, and later by Brown-Séquard. Giard's parasitic castration should also be mentioned. But systematic study began only after Bayliss and Starling (1902) had named the hormones and made them a popular subject. A great influence upon the rise of this field of study was exercised by the early work of Steinach, with his emphasis upon the role of the interstitial cells in mammals. Pézard, Danforth, and the school of F. R. Lillie had a similar influence upon the study of the sex hormones in birds, and Witschi, Harms, and Ponse for amphibians. It is hardly possible to report in a short space upon all the progress zoologists have made in this field. Only a few important lines of work can be mentioned. In mammals the study of the freemartin and its hormonal interpretation by Keller and Tandler had a great influence upon the progress of the work, especially after Lillie reported the same facts and explanations. Innumerable studies followed all over the world, using different techniques for the study of mammalian hormones (e.g., Sand, Lipschitz, Moore, and their students). The especially attractive field of secondary sex characters of birds was explored in innumerable experiments (e.g., Lillie, Crew, Zavadovsky, Domm, Bénoit, Morgan). A great step forward was made when the school of Lillie introduced embryological experimentation into this field (Willier, Hoadley), and the more recent chemical isolation of sex hormones has permitted direct injection of hormones into the embryo (Willier, Danchakova). Much information of elementary importance for the understanding of sexual differentiation was gained by a combined genetical, embryological, and endocrinological study of the amphibia inaugurated by Witschi, after R. Hertwig's pioneer experiments. The introduction of the methods of parabiosis and of embryonic transplantation brought further important results (Witschi, Burns, Humphrey), and this field of research is still flourishing. The rising tide of endocrinological research in regard to sex led also to experimentation on invertebrates. The absence of genuine sex hormones in insects was proved in experiments of Oudemans, Kopec, and Meisenheimer. But something which may be compared in a general way to the action of sex hormones was found in the sex-determining proboscis substance of Bonellia in Baltzer's famous experiments, supplemented by Herbst.

Among the other major hormones of the vertebrates, only two are connected with important zoological work. The discovery of the role of the thyroid in amphibian metamorphosis by Gudernatsch was highly consequential. Hypophysectomy and transplantation in relation to the sexual cycle have become a standard laboratory method of the zoologists (Allen).

One of the recent important lines of progress in the zoological study of hormones is derived from the discovery by Wigglesworth of genuine hormones in the invertebrates. The molting, pupation, and gonadotropic hormones of the different glands of internal secretion in the insect head are being intensively studied, and many future discoveries are expected. Another recently found type of invertebrate hormone, a pigmentation-regulating substance of the eyestalk of crustacea (Koller, Perkins), has led to interesting discoveries. Altogether, the zoological study of the internal secretions has not only resulted in an enormous body of important facts, but also led to deeper understanding of the integration of life processes in development, morphogenesis, organization, and function.

It is only fair to devote, finally, a paragraph to applied zoology, which has made immense strides. One may say that fisheries, as a science, has completely developed in this century, though the foundations were laid before. I mention the inquiry into the sources of food, both in the sea and fresh water; the introduction of agricultural methods into fresh-water fisheries (Hofer), including the study of fish diseases (Hofer, Plehn), food supply and its stimulation, artificial breeding, and stocking. In marine fisheries, work on the migration of plankton organisms and their dependence on physicochemical conditions has been a prominent development, and since Heincke introduced biometry into the study of fish taxonomy and ecology the mathematical approach has proved successful (Duncker, Schmidt). One field, study of the migration of fishes, has led to discoveries which are of importance far beyond the applied field; namely the elucidation of the life history of the eels (Grassi and Cotronei, Schmidt).

Another child of this century is applied entomology, at least as far as methods are concerned. The introduction of the method of fighting pests with the aid of their natural enemies is one of the great feats of that science (Howard, Silvestri). In the pursuance of this work much purely zoological research has been done on life cycles, growth, population mechanics, and ecology. Actually, the data of applied entomology are a treasure trove for the ecologist and evolutionist.

Animal husbandry is almost outside the limits of applied zoology, leaning most heavily on physiology, genetics, and biometry. But two recent fields belonging more to zoology should be mentioned. The scientific breeding of silkworms occupies many

zoologists and geneticists in Japan (Toyama, Tanaka), Italy (Jucci), and Russia (Kosminsky, Alpatov). To me, the most charming branch of animal husbandry is the production of cultured pearls by Mikimoto, started on a suggestion of the zoologist Ch. Ishikawa.

Parasitology, though applied zoology, is partly general, descriptive zoology and partly pathology and immunology. Its progress in the present century has also involved some discoveries of a purely zoological nature. Those relating to protozoa have already been mentioned. There are whole groups of pathogenic protozoa which, though known before, have come to the fore only in this century, such as malaria parasites, trypanosomes, and *Leishmanias*. Even in parasitic metazoa a few important zoological discoveries have been made, important as well for general zoology as for parasitology—for example, the life cycle of the hookworm and Medina-worm (Loos) and of Ascaris (Yoshida).

The present all-too-short review of zoology's progress in the first half of this century shows that the zoologists have reason to be proud of their accomplishments, though they rarely make headlines. One could add that these developments were aided considerably by parallel improvements in techniques. Most prominent is the wide use of experimentation, which goes so far that enthusiastic experimentalists treat nonexperimental work with derision. It is needless to say that today and always observation and description will form the foundation of zoology, and the unavoidable point of departure for experimentation. Another tool that is being used more and more is the application of mathematical methods both in descriptive and experimental work. Starting at the end of the last century with the work of the biometric school (Pearson, Weldon, Duncker, Pearl, Heincke, Hensen), and greatly influenced by the application of statistical methods to the analysis of the results of genetical experimentation (Johannsen, Fisher), statistical methods of description and check have permeated all fields of zoological research. In some fields (ecology, evolution) part of the literature has actually ceased to be intelligible to the nonmathematician (Fisher, Haldane, Wright). The rise of biochemistry has furnished the zoologist with tools for attacking basic problems of organic structure and function. Today the zoologists as easily speak of chain molecules and desoxyribosenucleic acid as, fifty years ago, they used the words entelechy or mosaic development. Ultramicroscopes, phase microscopes, electron microscopes, apparatus of ultraviolet spectroscopy (Caspersson), micromanipulators (Chambers), microscope centrifuges (Harvey), and Cartesian divers (Needham) are tools used in purely zoological work. But it will be good to realize that, just as general human progress is not measured in terms of motor cars, radio, and television, but in terms of great and noble ideas, so the past and the future progress of zoology depends first of all upon new, bold, and inspiring ideas.

ATOMS

Discover this tall slope of flowers,
And close your eyes and you can see in thought
A well of distances, the drive
Of worlds beyond our own,
Of strength around each stone,
And whirling atoms blowing storm on storm
In ceaseless lightning showers.
All of them have been caught
And brought to lovely form
Of which our senses drink and make alive.

DANIEL SMYTHE

Can Agricultural Science Save America?

RUSSELL COLEMAN

A native Mississippian, Dr. Coleman received his M.S. degree at Mississippi State, later being awarded his doctorate at the University of Wisconsin, where he majored in soil chemistry. His research has been concerned with the fertilization of commonly grown crops and scientific studies seeking to unlock the secrets of soil reaction. As president of The National Fertilizer Association (since 1948), Dr. Coleman is the moving spirit in the organization of a new NFA Plant Food Educational and Research Foundation, the purpose of which is to encourage the dissemination of information on the proper utilization of plant food so as to promote a sounder American agriculture.

THE rise and fall of past civilizations have caused some modern thinkers to predict the decay and dissolution of our own. The followers of Oswald Spengler and his *Decline of the West* are numerous and strong. While admitting our triumphs, particularly in the fields of science, they picture our inevitable doom.

Within our own country, men have arisen whose dire prophecies rest upon the premise that we have so mismanaged our soils that no recovery is possible. Whole civilizations have collapsed, they say, because it has been impossible to provide people with the food, feed, and fiber they have needed. And what is so radically different about the West, particularly America, they ask? Have we not exploited our resources and robbed our soils? Have we not set the stage for our own destruction?

Men like this need answering. For their arguments contain a major and a glaring error. They fail to recognize that the United States still abounds in rich resources, and that science has given us the knowledge and the tools with which to use these resources for our own salvation. Abundantly equipped with nature's blessings, we have learned how to set about doing the job.

Of all the tools man has devised, none is more important than fertilizer. The industry that makes fertilizer is not an old one. Its centennial is being celebrated only this year, but its future is even brighter than its past. Its importance cannot be gauged from industry statistics, for its 1,100 plants employ only some 32,000 workers, whose output last year was valued at about 600 million dollars. The significance of the industry to the nation's economy can be better illustrated by the statement of the U. S. Department of Agriculture that more than one fifth of America's farm production comes from fertilizer use. And the eminent soil scientist Firman E. Bear, of Rutgers University, has declared that "the fertilizer industry represents the most important advance ever made toward providing plenty of food for the peoples of the earth."

Concern about America's soil and crop problems has grown with the nation. Washington and Jefferson both recognized the importance of replacing the plant foods removed from the soil, and the agricultural leaders and scientists who followed them became more and more concerned because of the increasing rate of removal. They began a search for sources of plant food materials.

The first sources developed were by-products of other industries. Later, in answer to the ever-increasing demand, other sources were found in inorganic chemicals, which today offer us the only economical means of supplying our plant-food requirements. Along with constant progress in the search for new and better fertilizers, there also have been advances in learning the what, the where, and the why of fertilizer—the rates and methods of efficient use for less expensive crop production and more abundant life for the nation.

The achievements of the fertilizer industry are not accidental—they are the logical results of the combined efforts, patient and intelligent, of industry members, farmers, state and Federal officials, and agricultural workers and scientists. It is obvious that the sizable increases in crop yields that have marked the course of our agricultural history, par-

ticularly during the past ten years, cannot be attributed to fertilizer use alone. Improved plant hybrids and varieties, better tillage, wider application of soil conservation practices, better farm machinery, and new developments in control of weeds, insects, and disease have all played their part. But with each new development in agricultural science, there has come an increased demand for fertilizer use. For fertilizer contributes in a unique way to more efficient and more economical crop production and at the same time offers opportunities for solving one of the nation's greatest problems—conservation of the soil.

Although the fertilizer industry was born in Baltimore a century ago, it is only within the past decade that its development and growth have been phenomenal. In its early years the industry was largely confined to the Southeast, where oft-repeated plantings of cotton and corn slowly but surely drained the soils of their once-rich supplies of plant food.

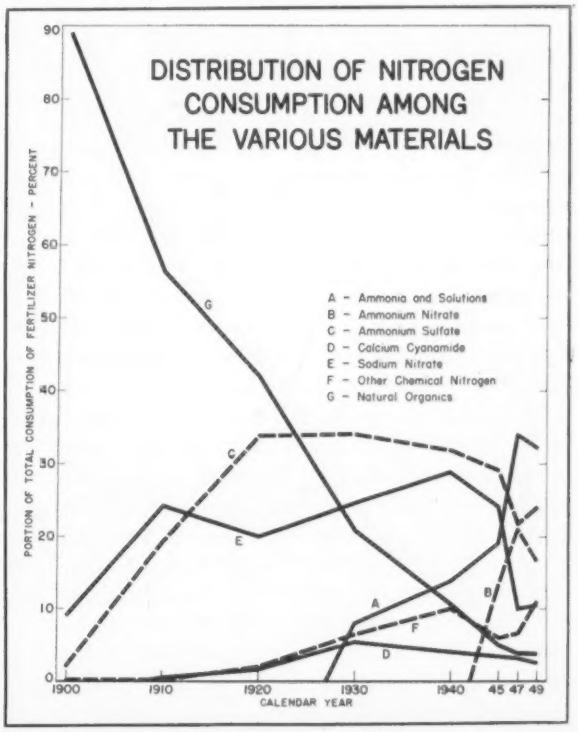
Today the industry is a national one, with its products used in every state of the nation. In 1949 our nation's fertilizer consumption registered its eleventh consecutive yearly increase in tonnage, with more than 16.5 million short tons of commercial fertilizer and fertilizer materials used by farmers in continental United States, compared with the considerably less than 8 million tons used in 1939. Increases in the use of fertilizer in some states have been sensational. For instance, in 1939 Illinois used some 41,000 tons; in 1949, the same state used almost 400,000 tons. Again, in Iowa in 1939, the consumption was some 13,500 tons, whereas the tonnage consumed in 1949 was almost 350,000 tons.

From the standpoint of tonnage alone, the principal use of fertilizer is in nitrogen, phosphoric acid, and potash. It may be appropriate to present some of the high lights in the manufacture of each of these three plant foods and to indicate some of the potentialities for the future.

Nitrogen

It is familiarly known that nitrogen, essential to all life, is vital to crops. It increases their protein content, promotes rapid vegetative growth, gives plants a healthy green color, and improves the quality of leaf crops. A century ago it was made available principally in the form of organics—guanos, manures, and certain organic wastes. Annual importations of guano from Peru amounted to tens of thousands of tons for some years, but today such importations are virtually nonexistent. The use of domestically produced organics increased up to about 1900 and included seed meals, dried blood, meat meal, tankage, ground leather, hoof and horn meal, and wool waste. At the turn of the century, consumption of commercial fertilizer nitrogen was 90 per cent natural organics, 9 per cent Chilean nitrate, and 1 per cent by-product ammonium sulfate. These three types of materials—natural organics, Chilean nitrate, and by-product ammonium sulfate—continued to furnish most of our fertilizer nitrogen for the next twenty-five years. But organic materials became more valuable as animal feeds and could not meet growing needs either as to economy or quantity, with the result that today the principally used nitrogen-bearing materials are inorganic. Beyond a doubt these inorganic materials are just as acceptable to plants as food as are organic materials—a fact proved by research at Federal and state experiment stations.

The progress in the production of inorganic fertilizer nitrogen has been given great impetus in the past fifty years by the development of by-product coke oven ammonia recovery and the fixation of atmospheric nitrogen by chemical and physical methods. In 1893 the first by-product coke plant was completed and started operation. In 1948 there were almost 15,000 by-product ovens at 86 different plants throughout the United States, producing 831,000 tons of sulfate of ammonia. Ammonia liquors, also produced from coal at coke ovens, totaled 24,753 tons of ammonia in 1948, equivalent



to 99,000 additional tons of sulfate of ammonia. Thus the recovery of nitrogen from coal in by-product ovens as sulfate of ammonia and liquors in 1948 equaled 930,000 tons of sulfate of ammonia. This is not the entire coke oven story, however. Synthetic sulfate of ammonia from purchased anhydrous ammonia has been produced at coke ovens during the last few years; the 1948 production was 30,749 tons.

Although the use of calcium cyanamide on a continuing basis was started at Niagara Falls, Canada, in 1909, the first commercial plant in the United States for production of fixed nitrogen by the synthetic ammonia process was placed in operation at Syracuse, New York, in 1921. During the past three decades other synthetic ammonia plants have been built, particularly under the impetus of war and postwar demands. The annual capacity of the 19 widely distributed plants producing synthetic ammonia has as a result been increased to about 1,400,000 tons of nitrogen. Even if the present international crisis should become more severe, there is little doubt that our synthetic ammonia capacity, together with our output of coke oven ammonia and natural organics, is sufficient to supply the domestic demand for fertilizer nitrogen, as well as nitrogen for chemical and industrial uses.

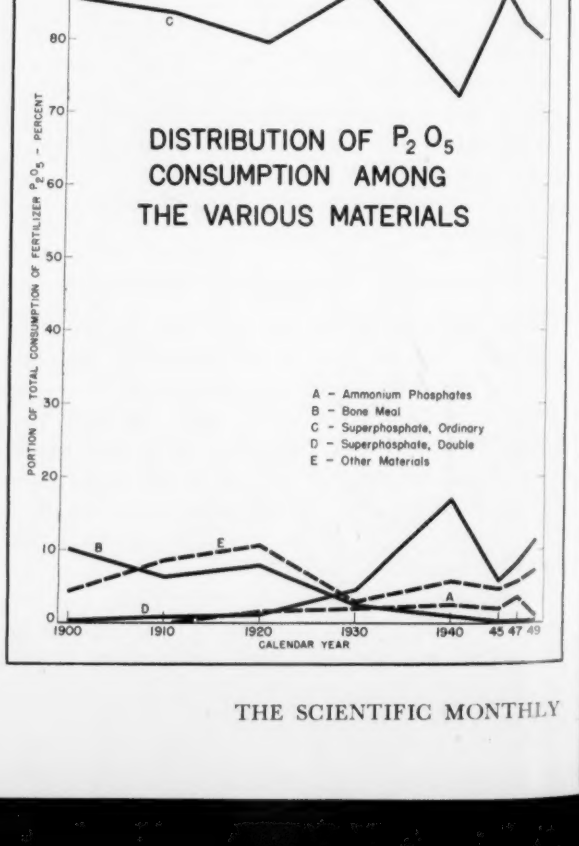
Modern technology has devised new ways for using primary products of nitrogen-fixation processes. Fertilizer grades of ammonium phosphate (36–59 per cent N and P_2O_5) have been manufactured in the United States from such products for more than thirty years. Efforts to develop other high-analysis materials suitable for agricultural use have resulted in large-scale manufacturing of fertilizer-grade urea (42 per cent nitrogen) and conditioned granular ammonium nitrate (33 per cent nitrogen), as well as several ammoniating solutions (37–45 per cent nitrogen), which are used in the preparation of mixed fertilizers. For some years anhydrous ammonia (82 per cent nitrogen) has been added to irrigation waters in certain parts of the West, and its direct application to nonirrigated soils in the Mississippi Delta area has come into extensive practice. The doors are by no means closed to further advances in the manufacture and use of nitrogen materials. Development of high-analysis, solid products having better physical properties and greater resistance to leaching from the soil is being sought. Possibly certain compounds of urea and formaldehyde may largely fulfill these requirements, and there is good prospect of their commercial production. Treatment of phosphate rock with nitric acid and ammonia offers the possibility of lower-cost, high-analysis fertilizers.

Phosphates

The active component of phosphates is phosphorus, an indispensable element for crops. It stimulates early growth and root formation, hastens maturity, gives hardiness to plants, and promotes seed production.

Vast natural deposits of phosphate rock sufficient to last for thousands of years provide our reserve of phosphorus. Large deposits of phosphate rock were first found in South Carolina and subsequently in Florida, Tennessee, and the West, with the result that the United States has been self-sufficient in phosphate raw materials for some eighty years.

In the early days of the phosphate industry, mining was done by hand, and the superphosphate was made in elementary fashion by treating the ground rock with sulfuric or phosphoric acid or by mixtures of the two. The raw phosphate and acid were mixed on a brick floor, the amount of each material being determined by trial beforehand. In other cases, the acid was run into a pit lined with bricks which had been dipped in hot tar to make them acidproof. The ground phosphate was thrown into the acid and stirred with rakes—a crude process, of course. As the product found favor with farmers, the demand increased and, as one would expect, primitive methods gave way to more efficient operation. The next step in manufacture was to go from a shallow pit to a den, which at first was



a square chamber lined with brick and sealed with pitch-pine tarred timbers held in position by iron bars. Later on, iron kettles served as mixing units. The mixed slurry, after being taken from the kettles, was poured into a den through a hole at the top. The den capacity ranged from 20 to 50 tons, later being increased to 100 tons.

For many years normal superphosphate (14–20 per cent P_2O_5) was the only type known, but more recently it has been demonstrated that some farmers can use a more concentrated product to advantage. Since 1920 there has been increasing use of this more concentrated product—known as double or triple superphosphate (42–48 per cent P_2O_5)—also of basic slag and ammonium phosphate.

The process for producing phosphates has remained essentially the same through the years, but the technology and manner of operation have gradually improved, until today completely mechanized, continuous systems of enormous capacity are being used. Today's product is relatively free from excessive moisture and free acid and no longer tends to get hard and lumpy in storage.

The present capacity for making ordinary superphosphate, exceeding 2.5 million tons of P_2O_5 annually, is found in some 200 plants located in 31 states, Hawaii, and Puerto Rico. The average content of available P_2O_5 is now about 19.5 per cent as compared with 14.5 per cent in 1900. Our annual capacity for making concentrated superphosphate is about 300,000 tons of P_2O_5 and is contained in 9 plants.

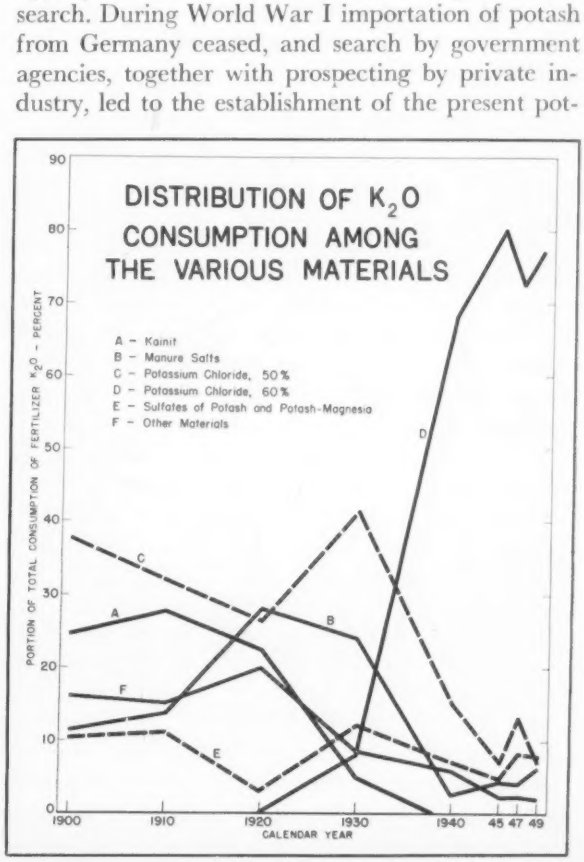
Because of its higher concentration, the costs of bagging, handling, and transporting concentrated superphosphate per unit of P_2O_5 are lower than those for ordinary superphosphate. These savings tend to counterbalance the lower manufacturing cost of ordinary superphosphate, so that in some sections of the country the concentrated product is the cheaper material on a delivered-to-the-farm basis. Also, concentrated superphosphate is an important source of P_2O_5 for manufacturing high-analysis mixed fertilizers. For these reasons, further marked expansion in the output of concentrated superphosphate is to be expected.

Quantity production of several new types of phosphate fertilizers has been achieved in the United States in recent years. These products are calcium metaphosphate (60 per cent P_2O_5), alpha phosphate, or defluorinated phosphate rock (20–28 per cent P_2O_5), and phosphate rock-magnesium silicate glass, or calcium magnesium phosphate (20 per cent P_2O_5). Preparation of fertilizers by processes involving treatment of phosphate rock with nitric acid and ammonia may come into use in this country. Production of potassium metaphosphate, a 100 per cent plant-nutrient material, has been studied experimentally.

Potash

Potash is an absolute requirement of crops. It helps to form starch and to produce strong stalks, imparts disease resistance to plants, and increases plumpness of grain and seed. Known potential and developed potash reserves in the United States are of such magnitude as to assure potassium for a hundred or more years to come. The chief deposits are found in the three Western states of California, Utah, and New Mexico.

When the first mixed fertilizer factory was established in Baltimore, the only sources of potassium were wood ashes and organic wastes, such as tobacco stems and wool scraps. After potash salts were discovered in Germany in 1856, a demand for their use developed in America, and the first imports were made in 1861. A long period then followed during which the United States was dependent upon foreign supplies, but in 1910 foreign contracts were canceled, and the extent of our dependence on such supplies became evident. In 1911 Congress appropriated funds to set up extensive government search. During World War I importation of potash from Germany ceased, and search by government agencies, together with prospecting by private industry, led to the establishment of the present pot-



ash industry. By the start of World War II, America's production was furnishing about one half of North America's requirements. Rapid expansion then took place, enabling this country to take care not only of its own mounting requirements but also those of Canada and some other Allies.

America's potash industry is highly mechanized. Down deep in the earth, giant machines remove the ore and bring it to the surface of the earth, or from potash-bearing surface-dry lakes, huge pumps collect the brines. Close by are refineries where the raw materials are concentrated for use as separate materials or in mixed fertilizers. Potash is extensively used in the manufacture of mixed fertilizers. In 1880 the average potash content of such fertilizers in this country was approximately 2 per cent. The average content for the year ended June 1948 was 7.1 per cent.

A major advance in potash technology is the production of nearly pure potassium chloride containing 60–62 per cent K_2O, which now supplies about 75 per cent of our consumption of fertilizer potash. Potassium sulfate, needed chiefly for the growing of tobacco, is now made domestically. Substantial quantities of sulfate of potash-magnesia are also being produced. In addition to solution methods of refining, flotation methods have also been successfully applied to the refining of soluble potash ores in New Mexico.

Secondary and Trace Elements

As the study of our soils has advanced, it has been discovered that other elements besides nitrogen, phosphorus, and potassium are necessary to grow good crops. Such crops require large amounts of secondary plant foods—calcium, sulfur, and magnesium. Calcium and magnesium come largely from our reserves of limestone and phosphate rock. Natural deposits furnish us with sulfur. These plant foods make up a large percentage of the necessary carriers and are included in all mixed fertilizers.

The trace element plant foods—boron, magnesium, copper, zinc, iron, and molybdenum—are also required by plants, if only in minute quantities. When advisable they are added to mixed fertilizers. Many soils contain sufficient quantities of them to meet the needs of present crops. Likewise, many fertilizer materials naturally carry some of these trace elements.

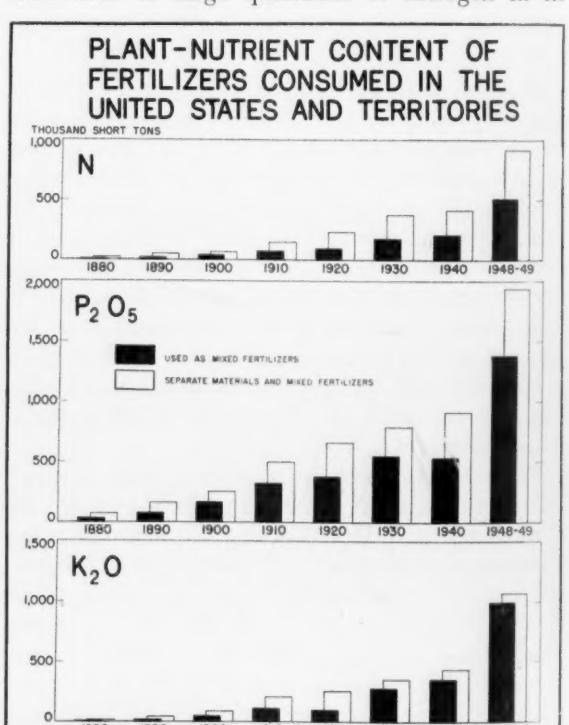
Mixed Fertilizers

A network of mixed-fertilizer plants, close to every farming area, covers the country. Their numbers have grown; so has their capacity. At the same time, notable advances have been made in manufacture and technology, a point of significance, because virtually three fourths of the tonnage of fertilizer nitrogen, available P_2O_5, and K_2O in the United States is used in mixed fertilizers. The advances that merit special attention include the increase in plant-nutrient content, the improvement in physical condition, and the preparation of non-acid-forming mixtures. In 1880 the total plant-food content of mixed fertilizer averaged only 13.5 per cent, but gradually this content has been increased until in 1948–49 it reached 22.6 per cent.

New materials of much higher analysis than those formerly used have become available in increasing quantities, and their use has been reflected in the production of higher-analysis mixtures.

Concomitant with the great expansion in the production of mixed fertilizers, the technical phases of their manufacture have undergone numerous changes. Factories have been brought to a high degree of modernization. Manual labor has largely yielded to mechanization. The physical condition of mixed fertilizers—formerly one of the industry's most troublesome problems—has been greatly improved.

Addition of free ammonia to mixed fertilizers—first practiced commercially in this country in 1926—has resulted in much improvement in the physical condition of the mixtures and has made possible the utilization of large quantities of nitrogen in its



cheapest form. The problem of physical condition still challenges the industry, however, and is one to which it continues to devote attention.

The General Outlook

What is the future of fertilizer use in these United States? There can be little doubt that the trend of consumption will be upward. As our growing population demands more and higher-quality crops, and as the drain of plant food from our soils in growing these crops becomes greater, the need for application of more fertilizer will be intensified.

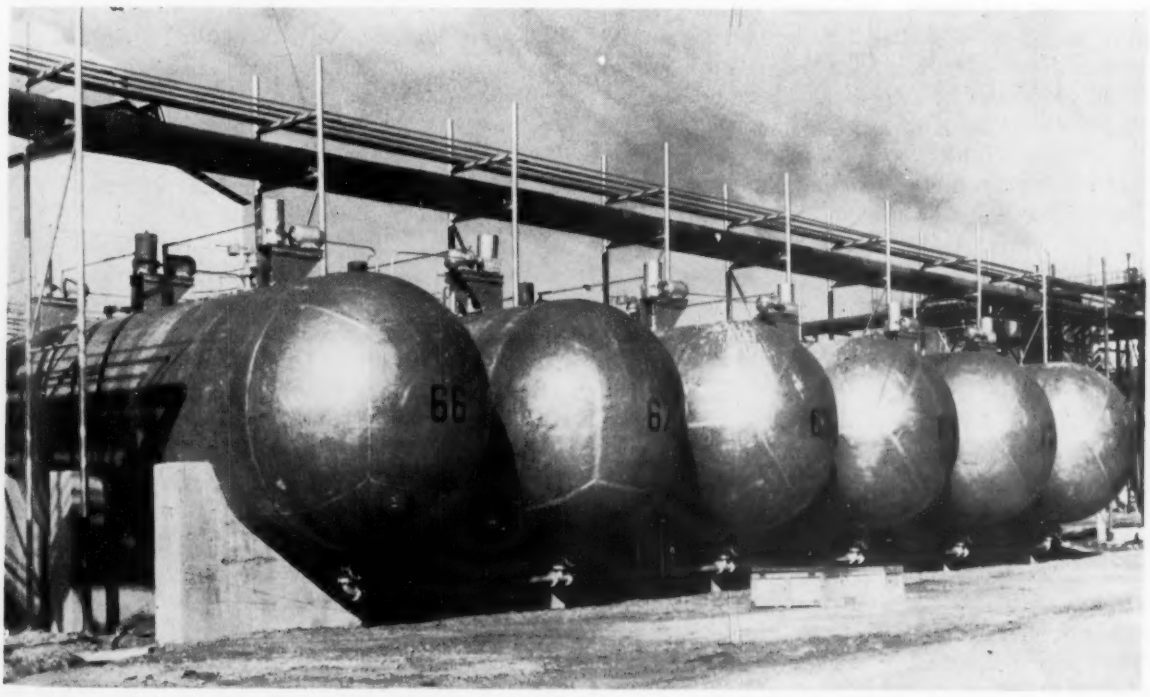
The tense international situation now prevailing emphasizes the importance of having the nation's agricultural economy in top condition. Should a third world war break out, fertilizer would be destined to play a major role in putting our agriculture into high gear. Its essential character was well demonstrated in World Wars I and II.

But fertilizer is vital to our economy in times of peace as well as of crisis. It is a cornerstone of economic agricultural production. In times of surplus, when farmers are required to produce less, their highest possible net profit per unit can be realized through efficient production. To achieve such production, fertilizers are essential. In periods of shortage, when farmers find it necessary to produce more, fertilizers are again required.

No matter what the economic situation, it is vital for the general welfare that we maintain the fertility of our nation's soils. Commercial fertilizers, the only means available for doing this economically, now account for 20–30 per cent of our total farm production. Fertilizers properly used may have to account, in the future, for at least 50 per cent of our total production of most crops.

The cumulative effects of intensified and widespread educational efforts to increase fertilizer use and to apply fertilizer properly are only now beginning to be felt. Only in recent years has the citizen outside the field of agriculture been made aware of the significance of fertilizer in helping to maintain his high standard of living.

The fertilizer industry has been able to carry out its responsibilities in an increasingly efficient manner only by taking advantage of scientific triumphs, Development of better ways of mining ores, discovery of methods of producing the most efficient materials, unearthing the secrets of plant food needs in our soils, devising better methods of applying fertilizer and developing machines to perform the work—these are but a few of the steps in scientific progress which have made achievement possible.



Huge aluminum tanks used for storage under pressure of nitrogen fertilizer solution (photo by Lion Oil Company.)

Fifty Years of Progress in Nutritional Research

E. V. McCOLLUM

Now professor emeritus of biochemistry after twenty-nine years of active teaching at The Johns Hopkins University, Dr. McCollum has contributed both to nutritional research and to the advancement of nutritional science by participation in the work of the Permanent Nutrition Commission of the League of Nations and the vitamin advisory board of U. S. Pharmacopoeia. *His broad interest in the biochemistry of nutrition is reflected in his extensive research on vitamins and mineral nutrients.*

AT THE beginning of the twentieth century the outstanding investigator of human nutrition was Wilbur A. Atwater, of the United States Department of Agriculture. He had studied in Europe and was considered to be an authority because of his numerous researches on foods and on energy metabolism. He believed that an adequate diet could be accurately defined as one that provided sufficient amounts of protein, and of energy (calories) in the form of carbohydrates and fats. He did not discuss the needs of living creatures for inorganic or mineral elements. He had, apparently, complete faith that the standard method for food analysis, which had been designed in Germany about 1860, and by which the above-named constituents were determined, gave reliable information about the nutritive values of foods. He realized that it is the digestible portion of what is eaten that is of significance and he determined, in the course of fifteen years, the chemical composition of every food commonly eaten by people in the United States, their respective caloric values, and the digestibility of many of them. Like others, he conducted numerous dietary surveys to determine what people ate when guided by their appetites and their purses and accepted the view that the data thus obtained really indicated the actual bodily needs of the individuals studied. He made many studies of the energy needs of men and women when doing various kinds of work and when at rest. On the basis of these kinds of information he felt justified in offering advice to the women of America on the economic side of food purchases. He advised them to buy their protein and energy in the form of foods with the lowest cost; consequently, he recommended cereal flours and meals and beans and peas as the most sensible investments, and listed the water-rich fruits and succulent vegetables as uneconomical purchases because so little protein and so few calories were secured for the food dollar.

It was fortunate for his peace of mind that Atwater never tested, on an animal, his views as to the adequacy of his chemical analysis as a source of knowledge concerning food values. Indeed, had the women of America followed his advice in the feeding of their families, it would have been a national calamity. Fortunately, no great number of persons seem to have been guided by his instructions.

Throughout the last half of the nineteenth century many agricultural experiment stations were established in Europe and America, and in them numerous experiments were conducted to learn the best methods for feeding farm animals. Many thousands of analyses of feeds were made, and rations were compounded from the data on the basis of certain feeding standards recommended by men who spoke authoritatively but without benefit of exact knowledge. By the year 1900 it had become evident that there were great disparities between the calculated and the real results of feeding animals, whether for growth or for milk, wool, or egg production, when the quality of the rations was estimated on the basis of chemical composition. Obviously, too much faith had been placed in chemical analysis as a source of information about quality in foods and feeds. Practical animal husbandry pointed clearly to the need for some new approach to the study of foods and nutrition. Food chemists were of the opinion that what was needed was a greater refinement of techniques of analysis, but they did not know for what to analyze, and they saw no way of finding out.

Soon after 1900 attempts were made by Pekel-

haring and by Hopkins to try the effects of feeding small animals rations composed of proteins, starch, sugar, fat, and a mixture of inorganic salts from laboratory bottles. These promptly ended in failure. The animals (rats) began to fail in health from the day they were restricted to these so-called purified diets. Small additions of natural foods, especially of milk, to the purified mixture produced remarkable improvement in the condition of declining animals. The conclusion was unmistakable. There must be in natural foods essential nutrients of which the food chemists were ignorant, and which they did not know how to estimate. Experience suggested that the way to solve the problem of appraising the nutritive values in foods lay in basic researches in which mixtures of purified food substances, known to chemists, would be supplemented with other known chemical substances, in the hope that what was lacking nutritionally in such inadequate rations might be ferreted out.

The earliest study that was productive of illuminating results was made in 1912 by McCollum and Davis at the Wisconsin Experiment Station. They found that a certain basal diet would support growth and keep the eyes of experimental rats normal, when it contained either butterfat or egg yolk fat, but when it contained either lard or olive oil growth ceased and the eyes developed xerophthalmia. They made soap from butterfat, dissolved it in water, shook the solution with olive oil, and then recovered the latter and found by a feeding test that it had acquired the nutritive properties of butterfat. Before this time it had been believed that, since all fats are about equally digestible, and one gram of each yields, on burning, about the same number of calories of energy as heat, they must all be essentially alike in nutritive value.

The second distinctly revealing experimental approach was also made by McCollum and Davis. They found that young rats cannot grow when restricted to any cereal grain such as corn, wheat, oats, or the like. A logical approach to identifying the nature of the fault or faults in such single natural foods was to add some known nutrients to one or another of the cereals to see how animals fared on the supplemented cereal diet. Thus wheat plus a pure protein, the casein of milk, was found to prevent in some degree the rapidity of nutritive failure; wheat plus a calcium salt was even better than wheat and protein; and wheat plus whatever is contained in butterfat or egg yolk fat, but not in lard or olive oil, also improved the health of young rats. Yet none of these supplements was able to produce a healthy animal capable of growth. No two of the supplements together—although the combination proved to be distinctly better than the single supplements—could promote abundant health in the rats. When all three kinds of supplement were simultaneously added to wheat, however, the young rats confined to the mixture flourished, in surprising contrast to any that were fed the simpler mixtures. It thus became clear that wheat (or other cereal grains) is deficient from a dietary standpoint in certain amino acids supplied by casein, but not sufficiently abundant in cereal grain proteins, and also in its content of calcium and in the substance distinguishing butterfat or egg yolk fat from other fats such as lard. This type of experiment constituted a biological analysis of a food and yielded data that could not be secured by the standard chemical analysis. The biological method for examining foods was soon extended to supplementing individual natural foods not only with the materials named above, but by extracts and concentrates of other foods, and then noting whether such additions improved diets that were otherwise incomplete for the nourishment of a young animal.

Since the epoch-making discovery of Eijkmann in Java in 1896, it has been known that if birds are restricted to polished rice as food they soon develop a multiple neuritis, highly suggestive of the human nutritional disease beriberi, a disease of the nervous system that afflicts people who subsist largely on a diet of polished rice. Birds fed whole rice did not manifest these symptoms. Accordingly, in Java, whole rice was provided to the inmates of prisons and asylums where beriberi was a scourge, in place of the polished rice that had been the staple article of diet. The results were clear-cut and impressive. Beriberi was eradicated from all those institutions where substitution of whole rice was made. This was the first human nutritional disorder to be understood as to cause and method of effective treatment. A quarter of a century later the substance preventive and curative for this disease was isolated from rice polishings in crystalline form by Jansen and Donath in Holland and by R. R. Williams in America. It is now known as thiamine and is synthesized in large quantities. It has become a familiar chemical, one of the best-known vitamins.

In the year 1900 there were four great human scourges resulting from inadequate dietaries, the causes of which were either unknown or controversial, namely, beriberi, scurvy, pellagra, and rickets. The solution of the problems underlying their etiology, and the means for preventing these diseases, which collectively have caused the ruination of an appalling number of human lives, is now complete, largely as a result of investigations made during the past fifty years.

As early as 1750 James Lind, a Scottish surgeon, had demonstrated that scurvy can be prevented or cured by eating fresh fruits or vegetables. The prevention of the disease on shipboard and in armies had a long and reasonably successful history. Yet experience was not sufficient to prevent, during the 1890s, and even up to 1915, the common affliction of bottle-fed infants with this disease in the United States. Scurvy was almost a new disease of infants at that time. The importance of pasteurizing milk, as a measure for the prevention of typhoid, scarlet fever, septic sore throat, and bovine tuberculosis infection, became so well known to physicians that progressive American cities adopted ordinances that required all market milk to be pasteurized. This advance in food hygiene was a blessing to all except bottle-fed infants, but to them it was a curse. The practice became common as the result of the teachings of certain German pediarticians that babies should be fed on a boiled milk formula supplemented with barley water. Every ingredient was cooked to destroy pathogenic bacteria. But, unwittingly, the heating destroyed the antiscorbutic principle provided by fresh, raw vegetable foods, and hence the babies so managed developed scurvy, frequently of a severe grade. The loss of food value caused by cooking foods was not generally appreciated.

In 1912 Holst and Froelich, in Norway, made a thoroughgoing study with guinea pigs which showed that any diet made entirely from dry or cooked foods would cause scurvy in these animals, whereas the same articles of vegetable foods, uncooked, would prevent or cure the symptoms of the disease. It was this study that led to an understanding of the necessity of giving daily to every bottle-fed infant a suitable amount of some unheated fruit or vegetable juice. Alfred F. Hess, of New York, made the earliest clinical study in scurvy-prevention in infants and popularized the new knowledge among clinicians. This new knowledge became general within a few years after 1915, with the result that infantile scurvy has become rare. Ascorbic acid (vitamin C), which is the antiscorbutic vitamin, was first isolated by C. G. King. Studies such as these had the further effect of forcefully calling attention to the need for including in the diets of persons of all ages a regular and adequate supply of antiscorbutic foods. There can be little doubt that a great many people in temperate regions, before the development of shipping facilities for economic marketing of easily perishable fruits and vegetables in cities during the winter months, developed some scorbutic symptoms during late winter and early spring, and were benefited in health by the availability of the earliest vegetable foods suitable for eating raw. It was in great measure as the result of faulty nutrition during the winter months that a number of "patent" "spring medicines" flourished for decades previous to the modern discoveries that form the science of nutrition. Fresh vegetable foods became available while sufferers were taking medicine, so the cure was naturally attributed to the latter rather than to the change of food.

Rickets, a disorder of growing bones, was for centuries extremely common, impairing the health and heightening susceptibility to respiratory infections, as well as causing skeletal deformities in infants and children. The cause of rickets remained unknown until 1922, when the disease was traced by McCollum, Park, and their associates to a deficiency of a substance which is not generally contained in ordinary foods except in small and inadequate amounts, but which is present in high concentration in the liver oils of many fishes. This substance, now known as vitamin D, was discovered in 1922. A few years later it emerged, through the brilliant researches of A. F. Hess and of H. Steenbock, that the beneficial effects of sunlight, especially mountain sunshine, in preventing or curing rickets are due to the action of the ultraviolet rays being absorbed by a substance known as a sterol, present in the skin, and that by this absorption the sterol is converted into vitamin D. The medical profession immediately began to utilize the new discovery, with the result that rickets has become rare, and the few cases still seen are of the mildest grades. The prevention of rickets and scurvy in infants and children has been of great significance in the physical development of the young.

Pellagra is a disease which, among the poor who have habitually subsisted on a simple and monotonous diet, followed the spread of the cultivation of maize in Egypt, Italy, Rumania, and some other parts of Europe. It remained of unknown etiology until about 1915, notwithstanding numerous theories as to its cause—including the supposition that it was hereditary—and many attempts were made to study its cause and prevention. As late as 1915, the Thompson-McFadden Commission, after a thorough epidemiological study of the disease in Georgia, concluded that it was transmitted by the stable fly. Through the brilliant studies of Goldberger, of the U.S. Public Health Service, carried on during a whole decade, it finally became clear that pellagra, too, is a dietary deficiency disease, caused by deficiency of the vitamin niacin. Wheat is about five times richer in niacin than corn. It is now known that a certain amino acid, tryptophan, a digestion product of proteins, can be converted in

the body into niacin, so that this amino acid is also pellagra-preventive. Today the principles of food selection are so well understood that it is common knowledge that the proper foods will prevent or cure pellagra.

From the earliest application of those methods which characterize modern research in nutrition, and which date from 1909, steady advances in knowledge have resulted from refinements in the planning of experimental diets, from observations of the effects of diets made largely of purified ingredients of known chemical nature, and from sustained efforts to separate individual chemical substances from extracts and concentrates made from different foods, to supplement diets that were not sufficient. These studies have resulted in a great body of knowledge which makes up our current science of nutrition. Chemists, unaided, indeed initiated modern nutritional research, but during the past three decades pathologists have rendered invaluable service by interpreting the meaning of symptoms specific for individual dietary deficiencies. They have thus aided in characterizing a considerable number of symptom complexes, each referable to the peculiar metabolic disturbances that follow when an organism is deprived of a single chemical substance which is an essential nutrient.

One of the later important discoveries in nutritional chemistry is that relating to the cause and prevention of pernicious anemia. First, it was found by Minot and Murphy in Boston that feeding liberal amounts of liver could bring about remission of the disease, and later it was found that a group of closely related chemical substances known as the folic acid group, which were first studied chemically and then produced synthetically by the chemists of Lederle Laboratories, were effective. Folic acid itself, discovered by Mitchell, Snell, and R. J. Williams in green leaves, was isolated from liver by Stockstad, and later studied chemically and its structure determined by R. B. Angier and fifteen associates. From these investigations has emerged the fact that there is in nature a folic acid group of related substances, of great nutritional significance. Still more recently the discovery of a cobalt-containing vitamin, B_{12}, has not only mitigated the lot of sufferers from pernicious anemia, but has revealed some very important secrets concerning the biochemistry of blood cell physiology.

New chapters in the literature of pathology have been added as knowledge has grown of the unique metabolic disturbances that arise from inadequacy of the diet in vitamins A, E, or K, in addition to vitamin D, already mentioned in connection with rickets. These are the fat-soluble vitamins, all others known at present being insoluble in fats but soluble in water. Chief among the latter group which have not received mention so far are riboflavin, biotin, and pantothenic acid. These, and also ten of the digestion products of proteins, the amino acids, are indispensable nutrients for human beings, and if one of them is supplied in the diet in inadequate amount a disturbance in the chemical and physiological processes of the body will occur which is not duplicated by the lack of any other indispensable nutrient.

Most surprising has been the discovery that such metallic substances as copper, manganese, zinc, and cobalt are vital elements in animal and human nutrition. These participate as constituents of certain enzyme systems, which will not do their particular jobs in the absence of the specific metal each one requires.

When we limit a discussion of nutritional research to the individual discoveries of the chemical substances that play roles in metabolism, and speak of the symptoms of the disorders which follow single, uncomplicated deficiency states, we fail to give a true account of the value of the great number of investigations by many workers, which now enable us to understand many things in physiology and pathology that were formerly unknown and mysterious. Especially valuable is our knowledge of the distribution in our natural foods of each of the essential nutrients, amino acids, vitamins, and mineral elements. Our knowledge of the properties of different foods as sources of these essential food principles underlies the current technology of food preservation, and the intelligent planning of daily menus with a view to making combinations of foods that complement one another in the essential constituents. In present-day meal planning preventive medicine finds one of its most important applications, one that ranks beside the great therapeutic discoveries that constitute the armamentarium of the modern clinician.

Wonder is the foundation of all philosophy; inquiry, the progress, ignorance, the end.
—MONTAIGNE, *Essays* (Bk. 3, Chap. 11)

Benjamin Thompson, Count Rumford

C. RAYMOND ADAMS

Dr. Adams (Ph.D., Harvard, 1922) has been a member of the Department of Mathematics at Brown University since 1923 and its chairman since 1942. Most of his previous writings have been technical papers in mathematics. His present article is based on a talk given before the Review Club in Providence, Rhode Island, last December.

EIGHTEENTH-CENTURY America produced two men who made notable contributions to science, Benjamin Franklin (1706–1790) and Benjamin Thompson (1753–1814), known in later life as Count Rumford. Neither was a graduate of college or university. This is not at all surprising, for the higher education of their times laid heavy emphasis upon the classics and was directed almost wholly toward the preparation of ministers and doctors. In contrast with Franklin, Rumford is little known among Americans today. His name is familiar to housewives who use a baking powder called "Rumford," and some New Englanders know Rumford as a section of the town of East Providence in Rhode Island, where the chemical works that manufacture the baking powder are located. The connection between the names of the Count, the locality, and the chemical works will appear in due course.

Thompson was born in Woburn, Massachusetts, on March 26, 1753. He was a descendant in the fifth generation after James Thompson, who emigrated from England as early as 1632, settled in Charlestown, and soon removed to near-by Woburn, first called Charlestown Village, where he was a subscriber to the original Town Orders* of 1640. The gambrel-roofed farmhouse in which Benjamin was born still stands in what is now North Woburn, about two miles north of the center of Woburn and about twelve miles northwest of Harvard Square, on the road to Wilmington and Lowell. The building is preserved by an association formed in 1878 for the purpose and is open to the public. About half a mile to the south is the colonial mansion once occupied by Loammi Baldwin, eight years Thompson's senior and his lifelong friend. Baldwin was a prominent patriot and a colonel in the Revolutionary Army; he developed the Baldwin apple and was a Proprietor and engineer of the Middlesex Canal, built in 1794–1803 to provide water communication between the Merrimac and the Charles rivers.†

Following a common school education, at the age of thirteen Thompson was apprenticed to John Appleton, merchant, of Salem, with whom he remained for three years. The next three years he was occupied in succession as an apprentice clerk in Boston, as a student of medicine with Dr. John Hay of Woburn, and as a schoolteacher in Wilmington and elsewhere. It was during this period that he and Loammi Baldwin used to walk occasionally to Cambridge to attend lectures by Professor Winthrop on natural philosophy—or physical science, as it would be called now. In 1772, when he was nineteen years of age, he was sent for by the Reverend Timothy Walker to teach in Concord, New Hampshire. Many years later Thompson spoke of his life as "checquered by a great variety of incidents." These incidents began in Concord, which for some thirty years prior to 1765 had been known by the name of Rumford.

The many biographical sketches of Thompson designate him variously as philosopher, scientist, administrator, philanthropist, etc. There are two

* The Town Orders were an agreement entered into by "all persons admitted to be Inhabitance in the said Towne": (1) to pay sixpence an acre for their land, (2) to surrender their land to the Town after fifteen months unless improved by a dwelling and some planting, (3) to fence in their "Catell," as well as their gardens and orchards, (4) to "entertayne no Inmate" without consent of the Selectmen, and (5) to cut no "younge Oake lyke to bee good timber, under eaight inches square."

† This canal was twenty-seven miles long, and its construction was something of an engineering feat in its day. It cost well over a million dollars, never paid a substantial dividend, and could not compete as a carrier with the Boston and Lowell Railroad after that was opened in 1834. The canal was abandoned in 1852 and sold for $130,000.

principal biographies of Thompson. The first is by George E. Ellis, who wrote a volume of nearly seven hundred pages to accompany the four-volume *Collected Works of Rumford* published in 1870–75 by the American Academy of Arts and Sciences in Boston. Ellis wrote in the style of his time and sometimes treated with charity the shortcomings of Rumford, as a Fellow of the Academy might perhaps have been expected to treat a benefactor of that organization. The second biogapher is James Alden Thompson, who refers to Benjamin as the second cousin of his great-grandfather and who addressed himself in 1935 to the task of removing the gilt from Thompson's reputation with a zeal that would do credit to a much closer relative. Quite without proper justification, many would feel, J. A. Thompson refers to Ellis' biography as a "soporific tome" whose "proper place is in some musty unused parlor of another day."

As a young man Thompson is characterized by his biographers as *ambitious, a climber, ever seeking to rise, essentially a courtier, a noble and imposing figure with great personal beauty, manner proud and haughty; aristocratic in appearance, he assumed aristocratic airs.* In concluding his volume, J. A. Thompson sums up his victim thus: *Brilliant mathematician, pioneer in the field of light and heat and a scientist of the first rank, utterly devoid of humor and humanism; hard, brittle, self-ientered from first to last.* Except for the fact that Rumford has never been considered by mathematicians to be a member of their group, brilliant or otherwise, these descriptive terms are all fairly suitable. The original sources of material on Rumford's life, aside from his published scientific papers and essays, are largely letters—his letters to his mother and his daughter and to Baldwin, and letters to and from many others with whom he had social or business contacts. Many of these letters were preserved by his family and by Baldwin's descendants; some are now in print, particularly in the biographies of Ellis and J. A. Thompson; others have been discovered in the Public Record Office in London, in the British Museum, and elsewhere only within the past twenty-five years. In any event, it is clear that Rumford was a colorful personality, and he did enough interesting and valuable things to warrant our sketching his career and giving attention to some phases of his work and writings.

We return, then, to Thompson, who had come to Concord in 1772 at the age of nineteen to teach school at the call of the Reverend Mr. Walker. Within a few months he married Mr. Walker's daughter Mrs. Sarah Walker Rolfe, whose first husband, Colonel Benjamin Rolfe, had recently died and left her what was regarded as a large estate. Through his wife Thompson met the colonial governor, Wentworth, who was impressed by his appearance and apparent ability and almost immediately commissioned him major in the Second Provincial Regiment of New Hampshire. This appointment, made when there were at hand many veterans of the French and Indian wars who felt themselves better entitled to it, aroused natural jealousies and was a first cause of Thompson's growing unpopularity among his neighbors in Concord. A little later he employed on his wife's farm two deserters from General Gage's army and presently returned them to Gage with a note requesting that they be allowed to come back without punishment. At the time this action was inimical to the Revolutionary cause, for such men were in demand by the rebels to serve as drillmasters; in fact, deserters who would thus serve were promised a reward of three hundred acres of land. Thompson also failed to take any part in rebel agitation. All this caused feeling against him to rise so high that he was forced to flee from Concord in 1774. Leaving his wife and infant daughter, he returned to Woburn.

The following May he was arrested and confined for two weeks in Woburn "on suspicion of being inimical to the liberties of this country." After a hearing he was released, but he was not given a public acquittal. Though nothing was proved against him, he remained under suspicion, and perhaps justly so. For it appears to be established that in 1775 he moved freely about the environs of Boston, particularly Cambridge and Charlestown, and perhaps occasionally in and out of Boston itself when it was in a state of siege. He frequented the American camp and offered to perform certain services for the American Army.‡ About twenty years ago the papers of General Gage were purchased in England and brought to this country by William L. Clements. These papers, now in the Clements Library at the University of Michigan, have been studied by Allen French and are the basic material for his book *General Gage's Informers* (1932). The papers in-

‡ In 1838, on what seems to be no more than heresay evidence, J. Johnston wrote, "Thompson was favorably introduced to him [Washington] by the officers and would probably have obtained command of the American artillery had it not been for the opposition of some of the New Hampshire officers." Colonel Baldwin, however, preserved a letter in which Thompson offered to procure insignia for the noncommissioned officers of the army.

clude a letter, part of it written in sympathetic ink (i.e., ink that is invisible until it is treated with a suitable chemical), dated Woburn, May 6, 1775, and with the signature cut out. By the handwriting and other circumstances, French is convinced that this letter was written by Thompson. It conveys military information and closes with a profession of loyalty to His Majesty George III.

In October 1775 Thompson made a trip to Rhode Island, boarded a British ship near Newport, and was carried to Boston. On November 4 he wrote for General Gage's successor, General Howe, a lengthy report concerning the numbers, disposition, and equipment of the American forces surrounding Boston. When presently (March 1776) Howe evacuated Boston, Thompson sailed for England.

In England Thompson entered the Colonial Office and soon became adviser to, and a favorite of, the Secretary of State for North America, Lord George Germain. At the latter's country estate in 1778 he made an elaborate series of experiments in the interior ballistics of small arms, and the following year, at the age of twenty-six, he was made a Fellow of the Royal Society. His ballistic experiments were continued with cannon in the Royal Navy, and he contributed a chapter to Stalkart's *Treatise on Naval Architecture* (1781). This chapter includes an original design for an armed frigate.

In 1780 Thompson was made Secretary of State for the Northern Department, which consisted of New England and New York and adjacent portions of Canada. In 1781 he was commissioned a lieutenant colonel in the British Army and sent to America shortly before Germain's enemies and critics, incensed by his inefficiency and lack of competence in prosecuting the war, forced his resignation. For three months Thompson was occupied with military matters in Charleston, South Carolina, and then for a year on Long Island (1782–83). Returning to England in 1783, he was promoted to the rank of colonel and he left almost immediately for travel on the Continent. The power and influence of his English friends had greatly diminished, and it is probable that Thompson felt that he might find a brighter future outside the country. With him on the Channel crossing was the historian Edward Gibbon, who wrote in humorous vein that he had as fellow passenger "Mr. Secretary Colonel Admiral Philosopher Thompson attended by three horses." After a few months Thompson entered the service of the Elector of Bavaria, where he was to remain for nearly fifteen years.

In Bavaria Thompson achieved great eminence as a public servant. Hundreds of beggars roamed the streets of Munich and frequently, with no good intent, the back alleys; he removed the beggars from the streets and gave them clean and comfortable quarters, food, and employment, if they were able to work, in his "House of Industry." The morale of the army was at a low ebb; the officers procured equipment and sold it to the enlisted men; the officers complained of too much paper work; the men were ill-paid and ill-clothed, and they had no occupation for the many hours in which they were not engaged in military matters. Thompson instituted extensive reforms in the organization of the military establishment and provided productive and interesting leisure-time activities for the personnel. He planned and executed a notably beautiful garden in Munich—which is still in existence and is known as the English Garden; he conducted numerous experiments in ballistics, primarily for the benefit of the army, and other experiments of substantial scientific value; he wrote numerous essays on these and other matters. At the age of thirty-one he was knighted by the King of England. At thirty-six he was major general of cavalry, privy counsellor of state, and head of the War Department in Bavaria. At thirty-eight the Elector made him a Count of the Holy Roman Empire and gave him the privilege of choosing his own title. He chose to be called Count Rumford, after the name by which Concord, New Hampshire, had been known prior to 1765.

In 1798 he was appointed envoy extraordinary and minister plenipotentiary from Bavaria to England, but the British government refused to recognize him on the ground that a British subject could not serve in this capacity. The next year he was offered the post of superintendent of the Military Academy and inspector general of artillery of the United States. The correspondence incident to this offer seems to conceal rather than to reveal fully the essential facts of the situation, and there appears to be some ground for the belief that the offer would not have been made had it not been expected that it would be refused.

At this same time Rumford was engaged in promoting the foundation of, and raising funds for, the Royal Institution of Great Britain, chartered in 1800 for "the speedy and general diffusion of knowledge of all new and useful improvements . . . and teaching the application of scientific discoveries to the improvement of arts and manufactures in this country and to the increase of domestic comfort and convenience."

The Institution presently comprised a museum where were exhibited models of useful machines and contrivances, a scientific library, and a research laboratory in which scientists worked and gave occasional lectures. For a large part of the years 1800–1801 Rumford resided in the building acquired by the Institution at 21 Albemarle Street, London, where he superintended renovations and installations of equipment. Of some four hundred pieces of furniture and equipment donated to the Institution during its first year Rumford himself contributed nearly half. It was he who in 1801 engaged Thomas Young as professor of natural philosophy and editor of the journals of the Institution, and Humphrey Davy as assistant lecturer in chemistry, director of the Chemical Laboratory, and assistant editor of the journals.

As the principal founder of the Royal Institution, Rumford performed a service which alone entitles him to be remembered with gratitude and respect. Prior to 1800 there were no institutional laboratories. Scientific workers, whether professors in universities or otherwise, conducted their experiments in their own homes, and the only students who had access to laboratory work were a few who, having attracted the attention of a professor by superior classroom work, were invited to his home to assist in his experiments. It was more than two decades later, in 1824, that the Rensselaer Polytechnic Institute was founded in this country and became the first educational institution to provide laboratory facilities for students; it was 1865 before the Massachusetts Institute of Technology opened its doors; and it was later still, in the eighteen-seventies, that the famous Cavendish Laboratory began operations at Cambridge, England.

The importance of the Royal Institution, however, derives not only from the fact that it was a pioneer undertaking, but also from the notable work of a succession of able men who were connected with it. Young (1773–1829) remained at the Institution only until 1803, when he resigned to devote more of his time to his work as a physician. He is known as one who did much to establish the wave theory of light, as an early worker in the field of physiological optics and the discoverer (1801) of the eye abnormality called astigmatism, and as the translator of the demotic text of the Rosetta stone. Davy (1778–1829), knighted in 1813 and created a baronet in 1818, remained at the Institution a large part of his life. He was distinguished both as a chemist and as a physicist; he discovered "laughing gas," and he invented the miner's safety lamp, doing the work under what would now be called a government contract. As a public lecturer on science, Davy attracted audiences as large as a thousand, and of him Coleridge, who attended his lectures "to increase his stock of metaphors," said "if he had not been the first chemist he would have been the first poet of his age." In 1813 Davy brought to the Institution the bookbinder's apprentice Michael Faraday (1791–1867), who was later to discover electromagnetic induction, the basic principle of electric motors and generators, and to be recognized generally as one of the greatest experimental scientists of all time. Faraday spent all the remaining fifty-four years of his life at the Institution.

The last dozen years of Rumford's life were spent largely in Paris and vicinity. His first wife having died sometime earlier (1792), he married in 1805 the widow of the celebrated French scientist Lavoisier. This marriage was unhappy, the parties to it being of very different dispositions and unwilling to compromise. On the second anniversary Rumford wrote to his daughter:

> A large party had been invited I neither liked nor approved of, and invited for the sole purpose of vexing me. Our house being in the centre of the garden, walled around, with iron gates, I put on my hat, walked down to the porter's lodge and gave him orders, on his peril, not to let anyone in. Besides, I took away the keys. Madame went down, and when the company arrived she talked with them—she on one side, they on the other, of the high brick wall. After that she goes and pours boiling water on some of my beautiful flowers.

Following a separation in 1809 that has been called "amicable," the Count removed to Auteuil, where he died in 1814.

Rumford bequeathed to Harvard University an annuity of $1,000, plus certain additional funds later to accrue to the university, to found a professorship "to teach by regular courses of academical and public Lectures, accompanied by proper experiments, the utility of the physical and mathematical sciences for the improvement of the useful arts, and for the extension of the industry, prosperity, happiness, and well-being of Society." This professorship was set up in 1816, and the third Rumford Professor (1847–63) was Eben Norton Horsford. In 1854 Horsford was persuaded by George F. Wilson to enter a partnership with the object of developing and manufacturing a chemical to induce bread-raising and "to give to bread made of bolted flour a 'deficient' ingredient which would add to the nutritious quality of the bread." Five years of successful experimentation led to the marketing of a calcium phosphate baking powder. The chemical company took its name from the professorship held by

Horsford, and the district in which the factory was located, then a part of Seekonk, Massachusetts, derived its name from the chemical works.

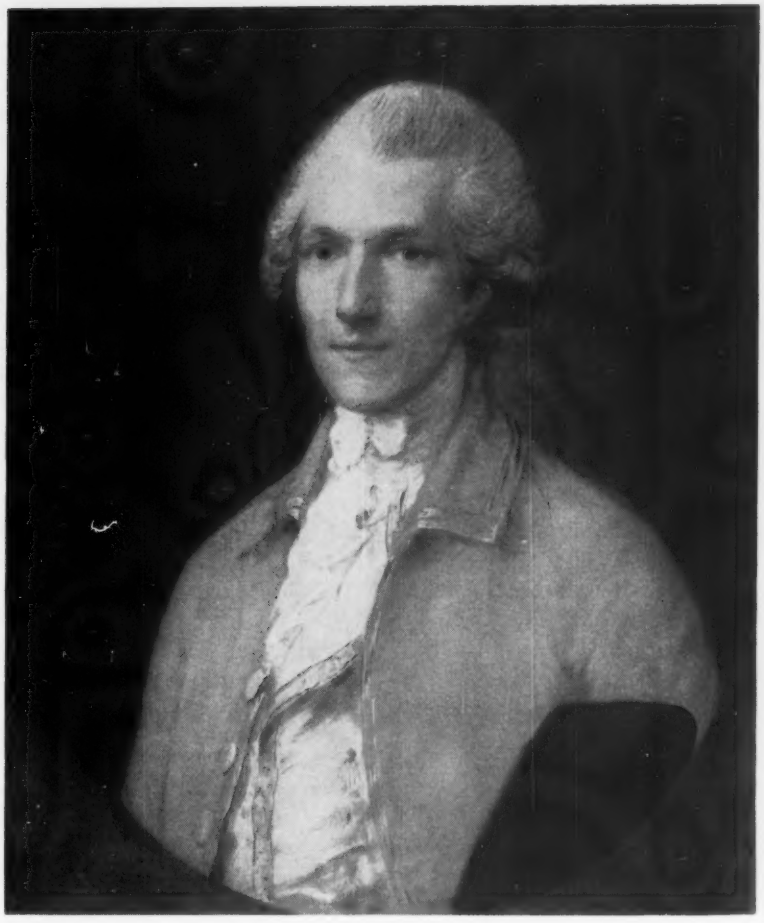
Among scientists, attention is directed to the name of Rumford by the periodic awards of the Rumford Medal, for work of outstanding merit on heat or light. These awards, one made by the Royal Society for work done in Europe, and the other by the American Academy of Arts and Sciences for work done in America, are made possible by gifts of Count Rumford in 1796 of £1,000 to each of these societies. Recipients of the American Academy's award include George H. Corliss, Albert A. Michelson, Thomas A. Edison, Percy W. Bridgman, Irving Langmuir, and Karl and Arthur Compton. The first award of the Royal Society's Rumford Medal was made to Rumford himself. Later awards went to Humphrey Davy, Michael Faraday, Louis Pasteur, James Clerk Maxwell, John Tyndall, Lord Rutherford, and Lord Rayleigh.

One occasionally hears Rumford's name coupled with that of Franklin. Both were born in or near Boston. Of the two, Rumford devoted a far larger part of his time to scientific investigation, and I believe most physicists would regard his contributions as the more valuable. In personality the two men were markedly different. Franklin was forty-seven years older; in his declining years (1788) he wrote to Mme. Lavoisier, "I enjoy here [in Philadelphia] everything that a reasonable mind can desire, a sufficiency of income, a comfortable habitation, a dutiful and affectionate daughter, . . , some old friends . . . to converse with, and more respect, distinction and public honors than I can possibly merit." At almost the same time (1785) Rumford, while still struggling for favor, wrote from Munich to his patron, Lord George Germain, in England:

> I certainly stand well with my Master and I think I have nothing to fear from his successor. . . . Rank, titles, decorations, literary distinction, and some small degree of military fame I have acquired (through your availing protection) and the road is open to me for the rest. No man supports a better character than I do and no man is better satisfied with himself.

Rumford certainly had many qualities of mind that are essential to a good scientist. He was observant and he was a keen observer; he had a strong desire to measure things and good sense in devising means of measurement; he had a good understanding of what it means to control an experiment. His writings exhibit an amazing range of interest. His acquaintance with gunpowder began as a boy in his teens at Salem when he set about making some fireworks to celebrate the repeal of the Stamp Act, and a premature explosion nearly had disastrous results. In later years he is reported to have said that before the age of fourteen he calculated a solar eclipse and observed it, and that the observation verified the computation as accurate to within four seconds. Recently (1937) the archives of the American Philosophical Society were found to contain a report submitted by Rumford of his observation in 1772, at the age of nineteen, of an aurora borealis as seen in Bradford, Massachusetts. Of his collected works more than half are devoted to his papers on heat. There are half a dozen papers on light, a few which might be classified under chemistry, and one on mechanics. It is natural that an experimental investigator such as he should for the purposes of his work devise some instruments and pieces of equipment; his inventions include a photometer and a calorimeter, both very good for their day. His interest in a scientific question did not stop with the answer itself; he always went on to the next problem—how can the answer be employed for better living and the benefit of society? He devised a stove (example at the chemical works museum), a roaster (example at the Rumford birthplace), and a multiple-wick lamp.

Just how did Rumford influence the thinking of scientists in a fundamental way? It was especially in connection with the concept of heat as a fluid. Everyone has observed that if a warm body and a cold body are brought close together heat passes from the warm to the cold body. For some centuries it has been common to speak of the heat as flowing, and this terminology suggests that heat be thought of as a fluid. If one thinks of heat as a fluid, what properties of a fluid does it have? During the eighteenth century it was common for scientists to think of heat as a fluid that they called "caloric." Bodies were believed to have a capacity for absorbing or holding heat much as a sponge is capable of holding water. When a body gave off heat the process was likened to the squeezing of a sponge, with the resultant expulsion of the water. The "calorists" were familiar with the idea that heat can be produced by rubbing two bodies together, but this they explained by saying that under pressure the caloric is squeezed out. Rumford carried out a protracted experiment in which a blunt drill was revolved for a long time under great pressure in the bore of a cannon, to show that the amount of heat which can be produced in this way is practically unlimited. Just as a sponge can hold only so much water, so a body could hold only



The Gainsborough portrait of Count Rumford. Reproduced by permission of The Fogg Museum of Art, Cambridge, Massachusetts.

so much caloric. Rumford's experiment thus gave strong evidence against the then common conception of caloric. Rumford contended that heat was actually motion, thus reverting to an idea current in earlier centuries.

Under the conception of heat as caloric it would be natural to raise the question as to whether heat has weight. This question was in dispute in the eighteenth century, evidence having been brought foward by some experimenters to show that heat is ponderable. Rumford conducted a series of interesting and delicate experiments to prove that heat does not have weight.§

We shall close with some quotations from Rumford's *Essays,* allowing the Count to speak for himself.

From his *Essay, Of the Excellent Qualities of Coffee and the Art of making it in the highest Perfection*:

> It [coffee] excites cheerfulness without intoxication, and the pleasing flow of spirits which it occasions lasts many hours, and is never followed by sadness, languor or debility. It diffuses over the whole frame a glow of health and a sense of ease and well-being which is exceedingly delightful. Existence is felt to be a positive enjoyment, and the mental powers are awakened and rendered uncommonly active. It has been facetiously observed that there is more wit in Europe since the use of coffee has become more general among us; and I do not hesitate to confess that I am seriously of that opinion. . . . What a difference between such a breakfast [with coffee] and that miserable and unwholesome wash which the poor people in England drink under the name of tea!

He describes seven coffeepots and urns, some of which we should now call drip coffeepots, and gives minute specifications for their construction and use.

From his *Essay, Of Food; and particularly of Feeding the Poor*:

> The idea of occupying a person a great while, and affording him much pleasure at the same time, in eating a small quantity of food, may perhaps appear ridicu-

§ In view of the modern conception of equivalence of mass and energy, it may be remarked that Rumford's comparisons of the weight of a body were made at temperatures in the range 26°–61° F. For such temperature differences, the relativistic change in mass is far too small to be measured even by the most sensitive instruments in use today.

lous to some; but those who consider the matter attentively will perceive that it is very important. It is perhaps as much so as anything that can employ the attention of the philosopher.

In this essay he considers in much detail the preparation of soups, the making of dumplings, the use of Indian corn; he gives the "approved receipt" for plain Indian pudding and recipes for numerous other foods. In all these considerations much attention is given to determining the most economical way of providing a nourishing meal such as was needed, for example, by the soldiers and the inhabitants of his House of Industry.

From his *Observations concerning the Salubrity of Warm Rooms in Cold Weather*: "There cannot surely be anything injurious to health in the genial warmth of 60° or 65°."

From his *Observations concerning the Salubrity of Warm Bathing* (and the principles on which warm baths should be constructed): Having been sent to Harrowgate in Yorkshire by his physician, he began bathing every third day. He describes the considerable advantage he found in bathing two hours before dinner rather than in bathing just before going to bed. He then continues:

As these favorable results appeared to be quite regular and constant I was induced to proceed to a more decisive experiment. I now began to bathe every *second* day, and, finding that all the advantageous effects which I had before experienced from warm bathing still continued, I was encouraged to go one step further, and I now began to bathe *every* day. This experiment was thought to be very hazardous by many persons at Harrowgate, and even by the physician, who did not much approve of my proceedings; but as no inconvenience of any kind appeared to result from it and as I found myself growing stronger every day and gaining fresh health, activity, and spirits, I continued the practice and actually bathed every day at two o'clock in the afternoon for half an hour in a bath at the temperature of 96° or 97° of Fahrenheit's scale, during *thirty-five* days. [Later in in this same essay he delivers himself of the following opinion on burning scented woods in the bathroom]:

Effeminacy is no doubt very despicable, especially in a person who aspires to the character and virtues of a man; but I see no cause for calling anything effeminate which has no tendency to diminish either the strength of the body, the dignity of sentiment, or the energy of the mind. I see no good reason for considering these grateful aromatic perfumes which in all ages have been held in such high estimation as a less elegant or less rational luxury than smoking tobacco or stuffing the nose with snuff.

IMMOVABLE OBJECT

This rock was not advised
  When waters chose their ways;
The stone was not informed
  By thrust of fusing rays.

Her base, bulged like a root,
  Resists the wave above her;
She lies, a solid shelf,
  Beneath too thin a cover.

Her bulk does not invite
  Tall ships the hurricane
Will flatten on her breast
  In this unsounded main.

If water shrink from earth
  And leave her bosom dry,
This mass will lie unmoved
  Beneath the naked sky.

WILLIAM NEWBERRY

Forestry's First Fifty Years

HENRY CLEPPER

The author, a Pennsylvanian, took his forestry degree in 1921. He has been a forester in the Pennsylvania State Forest Service and the U. S. Forest Service. Since 1937 he has been executive secretary of the Society of American Foresters and managing editor of the Journal of Forestry. *The Society is celebrating its semicentennial this year.**

THE rise of the forest conservation movement following the Civil War was a typical American phenomenon. It was initiated in the crusading zeal of a small group of public-spirited citizens who, paradoxically, demanded government protection of the nation's woodlands at a time when most citizens, if they thought of the matter at all, believed the forests of the United States to be practically inexhaustible.

During the 1870s a few neswpapers began to editorialize against the devastation of forests. In 1871 occurred the great Peshtigo, Wisconsin, forest fire—the most disastrous in American history; more than 1,100 people died, and 1.25 million acres were burned. A year later J. Sterling Morton, of Nebraska, assured himself a permanent footnote in history by his proposal of Arbor Day. Congress, too, gave recognition to the need for tree planting by passing the well-intentioned but ineffective Timber Culture Act. Thinking people here and there throughout the country were worrying publicly about the nation's indifferent handling of its natural resources.

In 1873 another incident focused attention on the need for the preservation of the nation's forest resources. Franklin B. Hough, of Lowville, New York, gave an address before the American Association for the Advancement of Science on the conservative use of natural forest areas. This speech led the AAAS in 1874 to address to Congress a memorial containing a recommendation that Congress create the position of Federal commissioner of forestry to collect statistics and information on the volume and distribution of the nation's woodlands, and on the consumption and waste of timber; on the influence of forests on climate, particularly with regard to agriculture; and on European methods of forestry. In 1876 Congress authorized the appointment of "a man of approved attainments and practically well acquainted with the methods of statistical inquiry" to make an investigation and a report on forestry. Dr. Hough got the job at an annual salary of $2,000. Five years later the small staff he had assembled became the Forestry Division of the Department of Agriculture, now the U. S. Forest Service.

Numerous other developments during the remaining years of the nineteenth century contributed to the cause. The American Forestry Association and several state associations were organized to disseminate information about conservation, and to provide a stimulus to further Federal and state action. The most important job to be tackled was the prevention and control of woods fire, then, as it is now, the most destructive enemy of the forest.

Toward the close of the century, then, there was an aggressive, even a militant, nation-wide forest conservation movement, but as yet no profession of forestry. The foundation of a profession was in the making, however. Two schools of forestry began offering instruction in 1898: the New York State College of Forestry at Cornell University and the Biltmore Forest School in North Carolina. Both were subsequently discontinued. But in 1900 the Yale School of Forestry and the Division of Forestry at the University of Minnesota opened their doors, and these two are the oldest forestry institutions in continuous operation in the Western Hemisphere.

At the turn of the century there were not many technically trained foresters in America. There were Gifford Pinchot and Henry S. Graves, who had obtained their training in Europe; several German foresters, the most prominent of whom were Bernhard E. Fernow at Cornell and C. A. Schenck at Biltmore; and a few others. When Mr. Pinchot became chief of the Division of Forestry in the Department of Agriculture in 1898, there were two technical foresters and nine other employees on the staff. To obtain technicians, the Division recruited so-called student assistants, young men with an aptitude for forestry who supplemented their instruction with practical field experience. In 1900,

* During the period December 13–16, the Society will celebrate its golden anniversary with a national meeting in the Mayflower Hotel in Washington, D. C. All friends of forestry, as well as all foresters everywhere, are cordially invited to participate in the Society's rededication of its professional resources to the national welfare for another fifty-year period.

61 student assistants were selected from 232 applicants. Organized in field parties, they were paid $25 per month and expenses. This corps of carefully recruited young men subsequently provided many leaders in the forestry profession. Thus the establishment of schools of forestry at a time when the government provided practically the only available jobs, and these few in number, was an act of courage and vision on the part of educational institutions.

On November 30, 1900, seven young men assembled in Mr. Pinchot's office to organize a professional society—this at a time when there were probably not more than a dozen Americans who had received instruction in forestry. Present at the meeting, in addition to Mr. Pinchot, were Henry S. Graves, Overton W. Price, Edward T. Allen, William L. Hall, Ralph S. Hosmer, and Thomas H. Sherrard. (At the time this is being written Dean Graves, Mr. Hall, and Professor Hosmer are still living and active in professional affairs.)

On December 13, 1900, the same group met again and adopted a constitution for the Society of American Foresters. Eight additional men were admitted to membership. Thus the Society began its existence with an active membership of fifteen. As other foresters became available and eligible they were elected to membership, and men prominent in conservation but not technically trained in forestry were elected as associate members. Among these was Theodore Roosevelt, who when President addressed the members at a meeting in the Pinchot home in Washington, D. C., where meetings were held for many years.

Professional Education

By the time of the first world war, 20 schools of forestry were in operation. Most of these were state institutions and offered a four-year undergraduate program leading to the bachelor's degree. Yale had the only wholly graduate school.

During the 1920s forestry educators proposed that a study be made of training of a forester. This study was made possible by a grant of $30,000 to the Society of American Foresters from the Carnegie Corporation of New York. Henry S. Graves, of Yale, and Cedric H. Guise, of Cornell, were put in charge of a "forest education inquiry" set up in 1929. During the next two years an exhaustive investigation was carried on, resulting in the book *Forest Education,* by Graves and Guise, published in 1932 by the Yale University Press.

Using this study as a foundation, the Council of the Society next authorized an examination of each of the schools of forestry to determine the minimum standards of training essential to qualify graduates for membership in the Society in the junior professional grade. This survey, begun in 1933 under the direction of H. H. Chapman, of Yale, resulted in the establishment of a list of 14 approved schools of forestry; six additional schools were listed as eligible for approval provided certain standards were met. Thus the principle of accrediting was first applied to forestry education in America.

Today 22 colleges and universities have schools of forestry accredited by the Council of the Society. These institutions provide professional training of a standard to warrant the admission of the graduates to membership in the Society without further proof of competence. The Society is at present undertaking a re-examination of all professional schools of forestry, and a new list of accredited institutions will be announced in 1951.

Although professional training in forestry varies in its several features from institution to institution, the curriculum in each of the accredited schools has a solid core of five courses. These are silviculture, based on plant ecology, botany, plant physiology, dendrology, and soils; forest protection from fire, insects, and disease; forest management, based on mensuration, surveying, and mathematics through trigonometry; economics; and forest utilization.

At least half the schools now offer graduate instruction leading to the master's degree. Yale and Duke are wholly on a graduate basis and, in addition to the master's degree, offer the comparatively new degree of doctor of forestry. As a matter of fact, the master's degree is increasingly recognized as essential for full professional training, and a doctor's degree is practically an essential qualification for teaching and research.

Since the first degree in forestry was awarded in 1900 (and in that year there was only one) the forestry schools of the United States have granted approximately 17,500 undergraduate and 3,000 master's degrees.

Research in Forestry

Early American foresters setting out to practice their profession were woefully handicapped by lack of knowledge of the growth, and response to treatment, of trees in forest stands. To be sure, an impressive body of scientific literature had been developed in Europe; but relatively little of this European knowledge, based as it was on a score of commercial tree species, had application in America, with its hundreds of commercial species.

A foundation for a forest research program had been laid in America through publications on trees by Michaux, Nuttall, Sargent, Sudworth, and

others, and by the early studies of forest growth of the Division of Forestry. Prior to 1900 the individuals possessed of scientific training who studied forest conditions were for the most part botanists and horticulturists. Compared with the relatively small amount of forest research then carried on, the extent to which it increased thereafter is another phenomenal development in American forestry.

In the old Division of Forestry a true research program was not possible because of an anomalous situation. The government's forests were in the Department of the Interior and its foresters in the Department of Agriculture. In 1905 President Roosevelt signed an act transferring the forest preserves, later to be designated national forests, from Interior to Agriculture, thereby putting the management of the Federal forests under the supervision of the government's foresters. Gradually the importance of research gained recognition, until in 1908 the Federal government formulated a plan for a system of forest experiment stations. Raphael Zon is credited with having been the architect of this plan, which culminated in 1915 with the establishment in the Forest Service of a Branch of Research.

Although the Federal record with respect to the development of forest research is impressive, the government was not the only agency promoting this necessary phase of forestry. Research was an adjunct of education almost from the establishment of the first schools of forestry. Moreover, some of the states which early created forestry departments undertook experimental work by conducting field studies in silviculture and by setting out sample plots, forestry's indispensable research tool.

What was to give a new impetus, as well as a permanent charter, to forest research was the enactment of the McSweeney-McNary Law in 1928, which authorized a research program largely under the direction of the Forest Service. It included a system of forest and range experiment stations, increased research in forest products, and a national survey of forest resources. Today the Federal government, under the supervision of the Forest Service, operates eleven regional forest experiment stations in addition to the internationally known Forest Products Laboratory at Madison, Wisconsin. The work of the experiment stations is further decentralized through the establishment of one hundred branch stations and research centers.

The Forest Service, however, is not the only Federal bureau engaged in forest research. Studies of tree diseases, particularly diseases of forest nursery stock and those affecting forest products, are carried on by the Division of Forest Pathology of the Bureau of Plant Industry, Soils and Agricultural Engineering. Likewise, the Division of Forest Insects of the Bureau of Entomology and Plant Quarantine has done notable work in forest insect control. A significant development in both forest pathology and entomology is the growing body of knowledge leading to the prevention of losses through improved forest management practices.

Among the states, New York was one of the first to investigate problems of operating tree nurseries and artificial reforestation. Pennsylvania, New Hampshire, Maine, New Jersey, Ohio, Wisconsin, Michigan, Minnesota, and California have all undertaken worth-while research programs, especially in forest management, and particularly in the fields of protection, silviculture, reforestation, forest influences, land use, and soils. Oregon, Texas, and Washington have initiated state-financed research programs, centered at especially built laboratories, for study in all phases of forest products utilization and wood technology.

At each of the twenty-two accredited schools of forestry, research in the production and management, as well as in the utilization, of forest crops is an integral part of the program. Institutions that devote sizable budgets to forest and wood-use research are the New York State College of Forestry at Syracuse University; Duke and Yale Universities; the Universities of California, Michigan, Minnesota, and Washington; and Oregon State College.

There is now an impressive amount of literature on the results of forest and wood-use research. The research program, with the Forest Service in the principal role, has progressed much further than the most imaginative person could possibly have foreseen at the turn of the century.

Forestry on Public Lands

The United States has the largest area of government-owned forests, under protection and management, of any nation in the world. Economically, the most important portions of these public lands are the national forests, administered by the Forest Service. Comprising 180 million acres, they contain one third of the nation's timber stand, one sixth of its commercial timberland, nearly all the important sources of Western water, and other related values, including range for livestock, recreation areas, and wildlife.

National forests have been established in forty states, Alaska, and Puerto Rico. They first came into existence in 1891, when Congress authorized the President to set aside forest reserves for the purpose of "securing favorable conditions of waterflows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United

States." Most of the national forests were proclaimed by three Presidents—Harrison, Cleveland, and Theodore Roosevelt—and they were set aside in the West because that is where the only extensive areas of public land remained. National forests in the East were established beginning in 1911 with the passage of the Weeks Law, which authorized the purchase of lands necessary to protect the flow of navigable streams. Subsequent legislation authorized the purchase of lands on watersheds for timber production.

The principle under which the national forests are managed is known as multiple-use, a system whereby land is made to serve the maximum number of uses, each integrated with the others. By way of example, timber-cutting methods may be modified from what may be the best silvicultural practice in order to stabilize water flow, or to protect scenic attractions, or to benefit wildlife, or to adjust grazing benefits. Although the concept of multiple-use management is simple enough to grasp, it is not so easily applied. That is why today's professionally educated forester is trained not alone in timber management but also in range, wildlife, watershed, and recreation management—in short, he must be a manager of so-called wild lands. Except where special laws or regulations provide for a single type of operation—as, for example, timber production only—most public forest lands are now under multiple-use management.

Another aspect of the administration of the national forests, true also of many other publicly owned woodlands, is that the goal is what is known as sustained-yield management; that is to say, the cut of timber is limited to the sustained productive capacity of the management unit.

About 4 billion board feet of timber are cut annually from the national forests. They now supply a little more than 10 per cent of the volume of national lumber production, plus enormous quantities of other products, including poles, mine timbers, railroad ties, pulpwood, and even Christmas trees. Perhaps the most significant point to be made about the economic importance of the national forests is that, with a shrinking reduction in privately owned stumpage, the demand for national forest timber is steadily climbing. The contributions of the national forests in grass for livestock, in water, in wildlife, in recreation, and in other benefits are of great economic importance also.

In the Department of the Interior, the Bureau of Land Management administers 30 million acres of timberland, exclusive of Alaska, most of it in the public domain. Also under Interior are some 16 million acres of woodland on Indian reservations, managed and protected by foresters in the Indian Service. In addition, the National Park Service is responsible for the protection of nearly 7 million acres of forest in national parks and monuments. The management of these lands is not for commercial purposes, but rather for the preservation of the forest species and types. Federal wildlife refuges, which are forested to the total of nearly a million acres, are administered primarily for the conservation of wildlife, but much of this land, too, is under intensive forest management. Finally, the Tennessee Valley Authority owns about one third million acres of timber, including 40,000 acres of plantations, all under management.

State acquisition of forest land began during the last two decades of the past century. New York, which started the creation of the Adirondack Forest Preserve as early as 1885, now has 3 million acres in state forests. Pennsylvania began her acquisition program in 1891, and now owns 1.7 million acres. Other states with sizable holdings are Michigan, 3.75 million acres; Minnesota, 2 million acres; Washington, 1.7 million acres. Idaho, Montana, and Oregon own less than a million acres each. Of the total of 16.6 million acres of state forests, about 14 million acres are owned by these eight states.

Most states now have forestry agencies under the supervision of technical state foresters. One of the most important of their functions is the prevention and control of forest fire. But this is not all the forestry job, by any means. Many states now render assistance to private woodland owners in reforestation, management, and marketing of timber. In general, the application of sustained-yield management on the state forests has been a slow process. The original purpose in the acquisition of state forests was to rehabilitate, by protection and tree planting, lands that had been largely devastated by clear-cutting of the timber followed by fire; hence improved management practices necessarily had to wait until the stand attained an age and size that would respond to cultural treatment.

One remaining type of publicly owned forest should be mentioned. This is the community forest, woodland owned by municipalities, townships, school districts, counties, or other civil bodies. Some 3,100 community forests contain 4.5 million acres. Of these, more than 1,100 are municipal forests, many of which are for watershed protection. There are some 1,200 school forests, and the remainder are owned by counties, townships, etc.

Forestry on Private Lands

According to estimates compiled by the Forest Service, there are 4.25 million private owners of

commercial forest land in the United States, with a total area of 345 million acres. Of holdings 5,000 acres or more in size, there are 83.5 million acres, held by some 3,500 private owners. With the exception of about 900 owners, the proprietors of these holdings are business organizations; these are the industrial forest lands of the nation. Of holdings less than 5,000 acres in size, there are 261 million acres, held by 4 million private owners, about half of whom are farmers.

Because forestry practiced on public lands serves numerous long-range social interests—watershed protection and recreation, to mention but two—it is seldom required to function at a profit. Although forestry on farm woodlands may, and often does, return a profit to the owner, it, too, may be successfully practiced without gain. Farm forestry may be carried on primarily for the control of soil erosion, for protection of land by the maintenance of shelterbelts, and for the production of wood supplies for home use. But industrial forestry—that is, forestry practiced on lands operated as a commercial enterprise—is a business. And, because it must pay its own way, it is as sensitive to the influence of gain or loss as the operation of any nonsubsidized industry.

As long as virgin timber was plentiful, and costs of wood were relatively low in comparison with similar materials, the practice of forestry on industrial holdings was not considered economically justified. But with the depletion of the original old-growth timber, with a consequent rise in the cost of producing wood, the competitive possibilities for practicing forestry became more favorable. Moreover, as long as cheap stumpage was available, the lumber industry was a migratory one—even large sawmills moved from one region of virgin timber to another. But there were some wood-using plants that could not cut out and get out. Pulp and paper companies had such heavy investments in land, plants, and water power that as they faced decreasing supplies of wood they had to choose between higher, often prohibitive, costs of transportation on pulpwood and managing forests to grow their own. Consequently, a few pulp and paper companies in the Northeast, where the assurance of sufficient supplies of raw material under company control was essential to permanent operation of the industry, were among the first to practice forestry. In time, some companies that had started out as sawmills increased their production to include the remanufacture of lumber and other by-products. Unable to migrate because of expanding investments and declining wood supply, they, too, settled down to timber growing.

During the past two decades there has been increasing public pressure on industry to do a better job of forest management. In several states legislation has been adopted providing for minimum cutting practices on private lands. The threat of such so-called regulation, especially by the Federal government, has undoubtedly aroused many private operators to a sense of their responsibility to the public welfare and the need to keep forest lands in productive condition. A growing awareness by industry of its need for forestry for permanent operation, and a conviction of the financial opportunities in it, are gradually improving industrial woods management.

Although the economic benefits of good forestry practices on farm woodlands were advocated more than half a century ago, little was done to stimulate farm forestry until the 1920s. Some of the early state forestry departments began operating nurseries for the production of forest trees for farm planting, but it was not until the passage of the Clarke-McNary Act in 1924 that a national policy of governmental assistance to farm woodland owners was adopted. This act authorized Federal-state cooperation in tree planting and forestry extension. Within five years, 31 states had organized cooperative extension programs with foresters in charge to render forest management assistance to farmers.

In 1937 the Norris-Doxey Cooperative Farm Forestry Act strengthened the program. Under this act, there are now 225 farm woodland management projects, covering 994 counties in 38 states. These projects are in addition to the educational and demonstration work carried on by the state extension services, under which there are now 68 extension foresters in 45 states.

In the numerous soil conservation districts, professional foresters employed by the Soil Conservation Service are available to help farmers with woodland management problems. About a dozen farm forestry cooperatives are active in providing management and marketing assistance to owners of small woodland properties. On the educational front the industry-sponsored Tree Farm program is helping mobilize the forestry agencies of many states to provide on-the-ground assistance in tree-growing to woodland owners.

Another indication of the growth of private forestry is the steady increase in the employment of trained foresters. According to a recent estimate by the Society of American Foresters, there are now about 4,000 foresters employed by industry, by other private woodland owners, and by private associations. Included in this estimate are foresters engaged in the production and utilization of forest

products, as well as in timber management. Also included are 250 technical consulting foresters, a professional specialty that did not exist in 1900.

Society of American Foresters

Compared with some of the professional associations, the Society of American Foresters in its fiftieth anniversary year is a mere stripling. In helping to develop a new profession the Society has benefited from the aid and guidance of senior organizations, and in representing the interests and standards of forestry, it has tried always to be worthy of its place in the family of professional and scientific societies.

In 1913 the Society became an affiliated society of the American Association for the Advancement of Science, with representation on the AAAS Council, and since that year it has enjoyed working relationships with other professional and scientific bodies. It has long been a member of the Division of Biology and Agriculture of the National Research Council; in 1947 a Joint Committee on Forestry of the Research Council and the Society brought out the book *Problems and Progress of Forestry in the United States.*

An interesting example of cooperation between societies is the Joint Committee on Forestry Equipment of the American Society of Mechanical Engineers and the S.A.F. The engineers are making studies for the improvement both in design and efficiency of machinery and equipment used in forest fire control. When the American Institute of Biological Sciences was organized, the Society was admitted to membership affiliation. It is also a member of the Natural Resources Council of America.

One of the Society's enterprises was a study of state forestry administration carried on cooperatively with the Charles Lathrop Pack Forestry Foundation, of Washington, D. C., under a grant from that organization. Over a period of three years, intensive surveys of the legislative, administrative, fiscal, and technical setup for forestry were made in ten selected states. Reports made to the governors and subsequently published recommended improvements in the states' handling of the forest resource. A gratifying number of the recommendations have subsequently been put into operation.

Full member-participation in the activities of professional and scientific societies is a goal that is seldom achieved. Although foresters are among the most gregarious of men, it is often difficult for them, especially the younger members, to attend professional meetings, because of their distance from urban centers. How to maintain the interest in professional affairs of the young forester located in the lonely mountain ranger station or remote logging camp is a problem constantly before the Society.

The Society has 25 committees, all with specific assignments, with a membership of 250. Its 21 regional sections and 70 local chapters utilize about 1,000 members as officers and committeemen. In addition, there are 10 subject divisions concerned with major fields of specialization, such as forestry education, forest economics, forest products, forest-wildlife management, and silviculture; their officers and committees employ another 100 or more. The *Journal of Forestry,* the Society's official organ, has an editorial board of 15; and the Council, the Society's directorate, numbers 11. All told, and allowing for duplication, the number of members participating in Society affairs is well in excess of 1,300, or nearly 20 per cent of a total membership of 6,700.

The *Journal of Forestry,* published monthly, has a circulation of 8,500. It is one of the world's best-known technical forestry periodicals. This magazine has had an interesting history. The first regular publication of the Society was the *Proceedings,* first issued in 1905 to record the papers presented at meetings. In 1917 the *Proceedings* was merged with the older *Forestry Quarterly,* which had begun as a student publication at the New York State College of Forestry at Cornell University, to form the *Journal.*

Occasionally the Society brings out books and bulletins of a technical nature. A recent book is *Forestry Terminology,* a glossary of technical terms used in forestry and related specializations. Another book, published in connection with the Society's semicentennial, is *Fifty Years of Forestry in the United States,* from which source many of the data for this article were drawn. A work in progress is the compilation of a *Foresters' Field Manual,* planned for publication late in 1951.

Without the Society of American Foresters it is unlikely that the forestry profession would have existed in its present form. By establishing creditable standards of professional education, by supporting an adequate forest research program for the nation, by providing a forum where foresters and others may debate issues and present technical papers, by adopting a code of ethics for the guidance of foresters in their business and professional relations, by providing a scientific journal as a medium for reporting the techniques of forestry practice, the Society has adhered to its objectives—the promotion of "the science, practice and standards of forestry in America."

International Preventive Medicine

PAUL F. RUSSELL

The author (M.P.H., Harvard, 1929), who is president of the National Malaria Society and president-elect of the American Society of Tropical Medicine, has been a staff member of the International Health Division of The Rockefeller Foundation since 1923. He saw field service in the Straits Settlements during 1925–28, in the Philippines in 1929–34, and in India in 1934–42, and was a lecturer in the Singapore Malaria Courses, 1935 and 1936. He has been a member of the WHO Expert Committee on Malaria since 1947 and was its chairman, 1949–50. He is currently chairman of the Tropical Medicine Study Section, National Institutes of Health, U. S. Public Health Service.

NOTHING on earth is more international than disease. Perhaps someday public health also will be universal, but at present there is plenty of scope for international preventive medicine, the history and modern practice of which are the subject of this article.

The word "international" implies something shared by the citizens of two or more nations, and certainly, over the centuries, this has been a characteristic of disastrous afflictions like typhus and cholera, malaria and yellow fever, and several others. History abounds with dramatic episodes such as the great pandemic of plague that devastated Asia and Africa and swept through Europe by way of Turkey, Greece, and Italy in the Middle Ages. Epidemic typhus fever also has caused immense international concern for many years—in fact, until the present time; and so has cholera—endemic and epidemic in India for ages, pandemic in Asia from 1816 to 1830, invading Russia, northeastern Germany, and England by 1831, then entering the United States by way of Quebec and New York.

One wishes there were space to elaborate these points and such stories as those of Captain Cook and of other explorers who carried tuberculosis, venereal disease, smallpox, and measles to the South Sea islanders. Another interesting chapter would be an account of yellow fever, which repeatedly sailed from country to country, affecting cities as far north as New York. Indeed, on the first and second of September 1858, the Staten Island Quarantine Station was attacked and destroyed by angry citizens who had been afflicted for fifty years by epidemics of yellow fever, which they

Above: Public health nurse talks with family group in isolated district in South America.

attributed to the laxity of the quarantine administration. The local courts sustained this riot as an "act of salutary and well-intentioned violence."

Such international visitations as have been mentioned date back to even earlier days; there has doubtless always been fear of invading plagues, as of enemy warriors. But one cannot say precisely when countries began to cooperate in combating disease. International preventive medicine, like other phases of medical practice, has developed slowly from dim notions which originated in prehistoric times and which cannot be clearly described. By the Middle Ages, however, men were so convinced of the communicable nature of plague that they put into effect against it some routine precautions affecting international commerce. For example, in Venice, as early as 1127, travelers from the Levant were detained and isolated in the House of St. Lazarus; in 1348, three guardians of the public health were appointed to do what they could to ward off the pandemic of plague that was approaching; and in 1374, by regulation, all suspected ships and travelers were completely excluded from the port of Venice. Ragusa in 1377 devised a more practical plan when it set up a *trentina,* or thirty-day detention, of ships and travelers from plague-infested areas. Marseilles in 1383 and Venice in 1403, as much on biblical as on hygienic grounds, lengthened this period of "dwelling apart" to forty days, or *quaranta giorni,* whence came our English word "quarantine."

For the most part, the early quarantine regulations were unilateral, and so it was a long step forward when in 1851 the French government convened in Paris an international quarantine congress of twelve nations to devise ways of combating cholera. As might have been expected, this early step toward international cooperation was a halting one, and the draft convention never received the necessary number of ratifications. Similar quarantine congresses were called in Constantinople in 1866, in Vienna in 1874, in Washington in 1881, and in Rome in 1885. In no case, however, did a permanent treaty survive. Finally, in 1892 a Venice conference resulted in the first International Sanitary Convention. Other international congresses were held, and, as the pathogenesis and epidemiology of some of the troublesome diseases became clearer, the international codes were revised and made more effective. Statesmen were learning that cooperation in quarantine was desirable, and so, at a Rome meeting in 1907, twelve nations, including the United States, created a permanent International Office of Public Health, with headquarters in Paris. This agency, which became active in 1909, gave continuous attention to the revision of sanitary regulations and acted as a clearinghouse for notifications of the occurrence of cholera, plague, smallpox, typhus, and yellow fever.

Prior to 1909 there were of course some sanitary conventions, but all intergovernmental correspondence regarding them went through departments of state and foreign affairs. No special secretariat existed to give effect to the provisions of such treaties. So the creation of the Paris Office International d'Hygiène Publique marked distinct progress because it provided an operating agency outside lay diplomatic channels. Owing in no small measure to this office, quarantine practice has continued to develop; indeed, the high degree to which transmission of communicable disease from country to country can be prevented is a triumph of international preventive medicine. But the office was limited in scope and was not concerned with aspects of public health other than quarantine and the notification of cases of communicable disease. Its operations were confined to its secretariat, and it is now merging with the World Health Organization.

The first modern international health agency that could cross frontiers of member nations was the Pan American Sanitary Bureau, established in 1902 in Mexico City at the second Inter-American Conference of the Pan American Union. In 1924 a treaty known as the "Pan American Sanitary Code" was ratified by all twenty-one American republics. The Pan American Sanitary Bureau receives and disseminates epidemiologic information, furnishes technical assistance on request of member countries, finances fellowships, promotes cooperation in medical research, and convenes sanitary conferences. Recently, it has begun to function also as the Regional Office for the Americas of the World Health Organization.

The Pan American Sanitary Bureau and all more recent similar official agencies are indebted to a private institution that has blazed a clear trail across some difficult terrain. When, in 1909, the Rockefeller Sanitary Commission began to cooperate with Southern state boards of health in an attack on hookworm disease, no one could have visualized significant world-wide implications. But the commission was merged into The Rockefeller Foundation in 1913 and became the International Health Commission, dedicated to "the promotion of public sanitation and the spread of the knowledge of scientific medicine," with the world as its field. It thus became the pioneer organization to undertake an operating program in the field of international preventive medicine.

Under impetus derived from the generous vision of John D. Rockefeller, Jr., and the early guidance of Wickliffe Rose, a layman of unusual wisdom—indeed, a *statesman* of public health—the International Health Division, as it has been called since 1927, has been shaped into a unique agency with a profound influence on the development of modern technics for the practice of international health work. As a prototype it has expressed a philosophy and set patterns of procedure for organizations seeking to foster international cooperative efforts against preventable disease. There are few countries anywhere which have not to some degree benefited in public health and in the practice of preventive medicine through bilateral or multilateral cooperation with the International Health Division of The Rockefeller Foundation, which operates "for the welfare of mankind throughout the world."

The modern period has also seen vast projects associated with war relief—in fact, there had never been anything in the past comparable to the Commission for Relief in Belgium, organized during World War I under the capable direction of Herbert Hoover. This became the American Relief Administration after the war, giving aid to eastern Europe. Both practiced international preventive medicine to a considerable degree. It is not commonly known that these projects persist to this day in the form of an active Educational Foundation which finances Belgian-American fellowships, including some in the sphere of public health.

In addition to American relief agencies, there was also an international Epidemic Commission, set up by the League of Nations in 1920 to deal with postwar epidemics. In 1923 the league established a Health Organization designed to provide a wide variety of preventive medicine services to countries all over the world. Prior to the modern period, international preventive medicine consisted very largely of the regulation of maritime commerce. But public health authorities had become increasingly aware that the world required more than this. There was need for an official agency through which every nation could share knowledge about preventable disease and public health practice—an international secretariat which would bring diverse forces into unified action against disease throughout the world. So the Health Organization of the league was created, marking a great advance in the development of international preventive medicine. Although the United States was not a member of the league, it did participate in the work of the Health Organization. For example, the surgeon general of the Public Health Service was permitted to be a member, cooperation was welcomed from outstanding American specialists, and generous financial aid was provided by The Rockefeller Foundation.

Private well and latrine in house in underdeveloped area. Such unhygienic conditions are a source of much preventable illness.

Time and war tend to fog memories, and today it is doubtful that many realize how great was the achievement of the Epidemic Commission and its successor, the Health Organization of the League. In the first place, through the efforts of these agencies, quarantine reform was stimulated, and numerous epidemics were effectively quelled. For example, typhus, spreading rapidly in the post-World War I disorganization, was threatening all Europe, but through coordinated international action much was done to halt the epidemic.

Another activity was an attempt to standardize sera and vaccines. There had been considerable confusion; for instance, a diphtheria antitoxin unit given the arbitrary value of 1 in Germany would have a value of 67 in the United States and of 2,500 in France. Much was also done to improve vital statistics by encouraging uniformity of reporting so that certain forms of cancer, for example, would not appear to be twice as prevalent in one country as in another just because classifications differed.

Epidemiological centers were set up in Geneva, Singapore, and Melbourne in order to supply member nations with regular bulletins of the prevalence of communicable disease. International study tours and lectureships to spread modern teaching were established. Certain diseases received special attention; for example, there was a Malaria Commission, and this became one of the more important parts of the Health Organization. The Commission stimulated and coordinated field and laboratory studies of vector *Anopheles* mosquitoes and of antimalarial drugs; it made important surveys and instituted courses of study, such as those held in Singapore in 1935, 1936, and 1937.

The Health Organization also convened international health conferences, provided sanitary safe-

guards for religious pilgrimages, and started a library of laws, decrees, reports, and other documents relating to public health. Finally, it continued to promote international cooperation throughout the field of preventive medicine, a most important objective because international ill will, jealousy, suspicion, inefficiency, and red tape were always limiting factors. The League of Nations Health Organization made substantial progress in a relatively short time.

World War II destroyed the Health Organization, as it did so many other institutions of cultural value. But it did not annihilate the idea or the ideals upon which the organization had been founded. Indeed, so firmly placed was the foundation that in the midst of bitter warfare in November 1943 it was possible to bring together in Washington representatives of forty-four countries to sign an agreement establishing the United Nations Relief and Rehabilitation Administration, commonly called UNRRA. Within a month's time UNRRA had established a Health Division, which in the following years carried out the largest international medical operation ever known, using a staff of 1,363 medical personnel of many nationalities. With headquarters in Washington and regional offices in London, Shanghai, Sydney, and Cairo, the division supervised the spending of more than 168 million dollars for health work and supplies.

Postwar criticism of action deemed necessary in the heat of battle is easy. Like all emergency and, therefore, hasty activity, UNRRA was bound to be expensive, and it was sharply limited with regard to long-range planning. Money had to be spent quickly, and undoubtedly there was some of that great waste inherent in war. But the fact remains that the UNRRA Health Division bridged the gap in the evolution of international preventive medicine caused by World War II. In addition to alleviating great suffering and hardship, it effectively fought typhus, typhoid fever, diphtheria, and malaria in Europe, cholera and plague in China, tuberculosis and malnutrition in many countries. For instance, UNRRA contributed more than 3 1/3 tons of 10 per cent DDT powder for typhus control. Thanks to UNRRA, to the Allied Medical Forces and Military Governments, to the United States Typhus Commission, to The Rockefeller Foundation Health Commission, and to many Allied scientists in government, commercial, and private laboratories, typhus was soundly defeated. Here undoubtedly was international preventive medicine of the highest order, and in it UNRRA had an important part. So, too, the UNRRA Health Division shared fundamentally in large malaria-eradication programs in Greece and Sardinia, cooperating in each case with the local government and, in the case of Sardinia, also with The Rockefeller Foundation. Thus it is clear that, although the UNRRA Health Division was devised as an emergency agency, yet it implemented some projects which will long have a beneficial influence on public health.

The most recent cooperative venture in international preventive medicine is the World Health Organization which, in effect, is the heir of the Health Organization of the old League of Nations. WHO was first visualized in San Francisco in 1945 at the United Nations Conference, where the basic importance of public health was recognized and the subject listed among those of major interest. A Technical Preparatory Committee of experts met in Paris early in 1946 and formulated a Draft Constitution. Later in the same year an International Health Conference convened in New York, fifty-one nations joining in setting up a World Health Organization Interim Commission. By April 7, 1948, the WHO Constitution had become activated through ratification by twenty-six member states of the United Nations (not, however, at that time by the United States). WHO itself was born officially on September 1, 1948, when the Interim Commission became the full-fledged World Health Organization, having today some seventy members and including the United States.

The work of WHO is carried out by three bodies: the World Health Assembly, consisting of delegates from each member nation; the Executive Board; and the Secretariat. The first Assembly met in Geneva in 1948, the second in Rome in 1949, and the third in Geneva in 1950. These Assemblies determine policies and take appropriate action to accelerate progress toward the organization's objectives. The Executive Board of eighteen members functions to give effect to decisions and policies of the assembly. The Secretariat, headed by a Canadian director general, consists of technical and administrative personnel. There are three assistant directors general, one for Central Technical Services, one for Advisory Services, and one for Finance and Administration, the first being an Indian and the other two American.

Certain Expert Committees and Panels have been established by the Health Assembly. Members are appointed by the director general, and they act simply as consultants, on request, in their respective fields.

Finally, within WHO there are regional organizations, each consisting of a committee, an office, and a director. These local agencies formulate

regional policies and supervise regional activities, thus decentralizing the field work of WHO. Besides the Pan American Sanitary Bureau in the Americas, there are other operating regions as, for example, those in the eastern Mediterranean and in southeast Asia.

The first and second World Health Assemblies for practical reasons assigned top priority in the WHO program to malaria, tuberculosis, venereal disease, infant and maternal hygiene, nutrition, and environmental sanitation. Specifically in the case of malaria, by virtue of insecticides developed in the past fifteen years, it is now feasible anywhere in the world to attain a high degree of control if suitable organization and trained personnel are available. In several countries, national, unassisted malaria control programs are well advanced, and in some cases, including our own, it is not rash to predict the eradication of malaria as an endemic disease in the next few years. In a majority of malarious areas, however, there is still great need for practical training, for effective organization, and for field demonstrations, all of which WHO, on request, helps to provide within the limitations of its budget.

One important distinction between the old Health Organization and the new WHO lies in the fact that the former was an integral section of a political body—the League of Nations—whereas WHO, following the example of the Pan American Sanitary Bureau, is a separate agency, an entity operating under its own constitution and merely affiliated with the United Nations. WHO thus can function directly as a technical body, without having to operate through the mazes of a lay political secretariat. This is clearly advantageous.

Of course WHO is far from perfection. Naturally some of the ideological controversy of the United Nations percolates into affiliated agencies. Nations that cannot have things exactly as they wish tend to become impatient. For example, the USSR and some of its satellites have withdrawn from active participation in WHO because they disagree with the majority in matters of policy. This is unfortunate but at the present stage not unexpected. The Health Organization was commonly said to be the most successful League of Nations agency. By and large WHO, seen in proper perspective, appears to be doing an even better job.

Specific dates are convenient, but events are developments and their influence is without end. Thus history makes it clear that the Health Organization of the League of Nations, the Health Division of UNRRA, and the World Health Organization of the United Nations have not sprung up out of the blue and are not revolutionary experiments in public health. They represent stages in the growth of international preventive medicine, comparable in their field to certain developments within the political and social sciences. Although WHO is not yet ideal, it has advanced in practical cooperative field work considerably beyond anything done by the League of Nations Health Organization. Such progress, however limited, is welcome, because most of us are apprehensive and uncertain over the immediate future and what we can do about it. A majority of mankind still lives by ancient behavior patterns, so that the doctrine of competitive survival predominates over the desire for international welfare. It is the hare of self-interest versus the tortoise of cooperative endeavor. In this race of the ages we should at least do what we can in our own fields to aid the tortoise.

We might, for example, give more thought to the development of multilateral public health efforts. Although American leaders in preventive medicine had a prominent part in laying the groundwork for WHO, the United States Congress has thus far given it reluctant and limited support. Slow to ratify the constitution, Congress arbitrarily fixed our annual participation in the budget of WHO at 1.9 million dollars (meanwhile appropriating tens of millions for short-term bilateral health aid and for "give-away" health projects set up on an expensive, so-called emergency basis in various parts of the world). A measure recently passed by Congress permits our annual appropriation for WHO to be increased up to 3 million dollars, thus making feasible a total WHO budget of some 7 million dollars a year. While, of course, too rapid expansion of such a new organization would not be desirable, yet the sum indicated does not seem out of proportion at the present time. This new bill met stiff opposition although, had it not been enacted, the United States would have been in the unenviable position of delaying a reasonable expansion of WHO. Such hesitant cooperation is regrettable, for Congress has repeatedly demonstrated great interest in public health. Doubtless this oposition is simply the reflection of a lack of active and informed concern on the part of laymen and most physicians about the subject of international preventive medicine. Perhaps here is a pebble some of us can help to remove from the path of the tortoise.

Space will not permit description of the many other American and foreign agencies operating in the field of international preventive medicine. An example that may be mentioned in passing is the United Nations International Children's Emergency

Rockefeller Foundation sanitarian discussing malaria control with a Greek family.

Fund, commonly called UNICEF. This is a post-war agency of the temporary crisis type, appealing perhaps more to the heart than to the head, spending tens of millions of dollars on food and supplies for child and maternal welfare. However, UNICEF is also carrying out the greatest immunizing project in history through its world-wide BCG campaign against tuberculosis, and it is financing malaria control demonstrations in the Orient and elsewhere.

Notable work is being done overseas also by Christian missions of many denominations, by the American and the International Red Cross, by the Institute of Inter-American Affairs of the State Department, and by the Division of International Health of the United States Public Health Service —a service which increasingly is developing an international outlook and which will have even greater overseas responsibilities in regard to the so-called Point Four Program. The division cooperates closely with the State Department in giving effect to provisions of such laws as the Smith-Mundt and the Fulbright Acts, each of which will eventually assist in a two-way exchange of students, some of whom will be interested primarily in public health. The State Department also has sent bilateral health missions to Liberia, the Philippines, and Greece, as well as elsewhere. The Economic Cooperation Administration has contributed large sums to overseas health work, as, for example, for malaria eradication in Sardinia. Still other official and private ways in which the United States is involved in the field of international preventive medicine could be listed. And one must not forget that various British, Dutch, Belgian, French, and other institutions, official and private, are practicing ably in the same field.

All in all, it is a notable record toward which the United States has contributed to an unparalleled extent. But one cannot logically be complacent. Probably three fourths of the world's inhabitants are still without sanitary environment, and perhaps never before in history have so many human beings been malnourished or burdened with parasitic disease. We in our country, with efficient national, state, and local health services, no longer have reason for great fear of foreign maladies, despite the fact that we are surrounded on all sides by a host of modern plagues, ranging from tropical fevers and bowel infections to Japanese B encephalitis. Germs are great travelers. There are fewer isolationists among the various species of pathogenic microorganisms than there are in Congress—and that is not very many. Furthermore, modern transportation greatly increases the chances of the entry of noxious or vector insects and of human carriers into many countries.

The subject of world public health has gained rather than lost in importance. The physical condition of hundreds of millions of people, hungry for food, makes them eager for that relief from the ravages of disease which the modern practice of preventive medicine can afford. The problems of society are complex and confusing, but twenty-seven years of the practice of international preventive medicine have emphasized at least one

Laborer with mosquito spray entering small dwelling in India.

Residual spraying against houseflies in Sardinia.

point: that no amount of political afflatus or free "hand-outs" will raise a debilitated, parasite-beaten community to significantly higher agricultural, economic, or social planes. Dollars and doughnuts are not enough! On the other hand, there may be surprising progress in the development of better agricultural methods, sounder land policies, and more logical political beliefs in a community which has been lifted from the depths of chronic malnourishment and parasite infestation by modern public health practice. Such practice comes to underdeveloped areas only by patient training of public health personnel and the development of reasonably well-organized national and local public health departments, by practical cooperation than by charity. Gifts of spectacular new buildings and thousands of gallons of sera and vaccines, the lending of dozens of experts who drop from the heavens here and there for a day or two of red carpets and hasty surveys in areas previously foreign to them, not only tend eventually to engender disrespect and ill will, but they usually fail to assist public health, however well intentioned. Incidentally, this illustrates a pitfall in the practice of international preventive medicine—one which WHO is attempting to avoid.

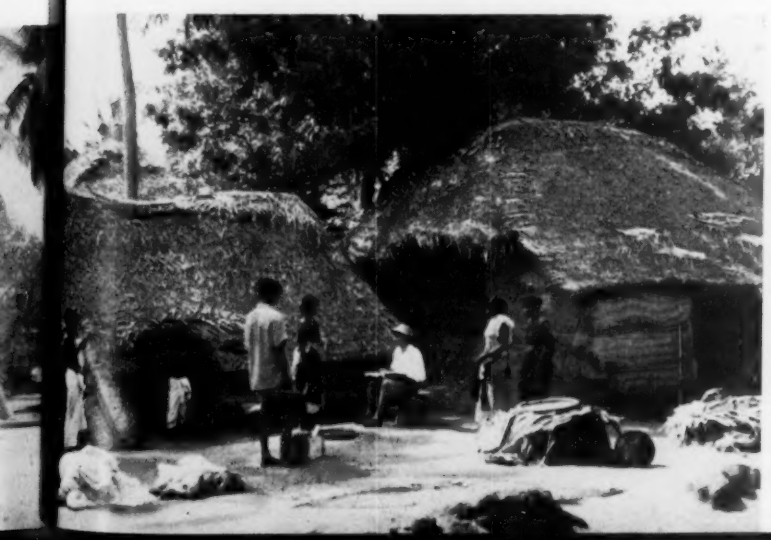
Finally, it is not alone for altruistic reasons that we must support international preventive medicine. It becomes increasingly important to reduce the incidence of those illnesses which, like malaria, lower the effectiveness of millions of farmers in potentially great food-producing regions of the world. Such diseases as the tropical fevers, which handicap laborers, also increase the cost of rubber, coffee, tin, certain fruits, assorted fibers, hardwoods, oils, and waxes. Industrial nations are thus affected because sickly peoples cannot afford extensive purchases of manufactured products. These aspects are probably more important than they appear to be at first thought.

So, too, the increasingly urgent and difficult problem of population densities requires international study, and it will not be solved by neglecting to attack communicable diseases abroad. One is as logical in hoping for earthquakes to clear away city slums as in depending on epidemic disease to lessen the pressure of overpopulation. In each case pooled intelligence is required, not forces which involve the indiscriminate sacrifice of human lives and institutions. Obviously, routine, long-term international cooperation is essential for progress in dealing with this and other questions basically affecting human welfare. A long time ago it seemed adequate to pray

> God bless me and my wife
> Our John and his wife
> Us four and no more. Amen.

That day has gone forever. We are now caught in a tangle of internationalism from which there is no escape but out of which could come a unity of order, public health, and welfare.

Sir John Simon in 1890, in his monumental work *English Sanitary Institutions* (Cassell Company, London), wrote of our planet gliding "by successive yearly rounds towards her last haven, whether



Doctor making a malaria-economic survey in South India.

of darkness or of light." He noted that in man, this planet's "paramount creature," the "beast of prey is not yet all extinct." However, man's "organs of higher life are in growth," and he continues to rise toward what Sir John called "the religion of mutual helpfulness." Verily, international preventive medicine is a vital part of a "religion of mutual helpfulness."

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Some High Lights of the First Half Century of Genetics

W. RALPH SINGLETON

Dr. Singleton's appointment as Senior Scientist at the Brookhaven National Laboratory in 1948 came as well-earned recognition of his long service as geneticist in the Connecticut Agricultural Experiment Station. Born in Missouri, he acquired his botanical training and background at such widely spaced institutions as the State College of Washington, Harvard, and the Universities of Missouri and Minnesota. As secretary-treasurer of the Genetics Society of America, he helped plan the Golden Jubilee of Genetics.

THE progress of genetics in the first half of the twentieth century represents the achievements throughout the life of this science. For most of the other sciences, this year marks only the mid-point in a century of remarkable progress. For genetics, however, the present century is practically the only one it has known, for the science really began in 1900* when three independent investigators, De Vries, Correns, and Tschermak, announced the researches that gave results confirming Mendel's original work in the 1860s.

Goldschmidt, in a recent article, eloquently summarizes the accomplishments of genetics:

> We come to the end of this admittedly incomplete record of the growth of genetics in the first half century of its existence. Looking back at the history of thought we realize that from time to time discoveries are made and ideas proposed which, though starting in an apparently limited field, at once illuminate all fields of human knowledge and force them to adapt their mode of thinking to the new insight. In the modern history of science such an event was Galileo's experimental work which started the new era of inductive science. Another one was the establishment of the theory of evolution by Darwin. Accepting the risk of being reproached with carrying too far the spirit of a jubilee, I state that the rise of genetics is another instance of discovery of new facts and of the conception of new ideas which have deeply influenced many fields of intellectual endeavor and the end is not yet in sight. Taxonomy and comparative anatomy, embryology and cytology, physiology and ecology have felt the impact. Evolutionary thought has been rejuvenated; paleontology has been forced to reconsider its basic tenets; zoology and botany have been welded together; eugenics and anthropology were given a solid basis; psychology and sociology have begun to take notice; biochemistry has not only been assimilated as a tool, but has received important stimulus in return. Medicine has been deeply influenced; bacteriology owes to genetics a new upsurge; and virology has assumed added importance; the philosophy of the organism is reconsidered and theoretical physics begins to introduce genetics into its most subtle deliberations. Geneticists may take reasonable pride in such performance and still more in the fact that progress has not slackened its pace and that the future holds no limits to further conquests.
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> More than four hundred years ago one of the most colorful figures of the Age of Reformation, Ulrich von Hutten, overwhelmed by the happenings of his day and the hope of a still greater future, exclaimed the famous words *"Es ist eine Lust zu leben"* ("It is a joy to be alive"). May I adopt this exclamation for the status of genetics today and close with the words: "Geneticists of 1950, *Es ist eine Lust zu leben!*" (*Am. Naturalist*, Sept.–Oct., 1950).

Goldschmidt's enthusiasm for genetics has had as marked an influence on other workers as have his researches.

It might be well to recall here some of the other geneticists of this century who have made large contributions, not only by their own researches, but by their ability to act as "catalysts" to stir the imagination of other workers. This is, obviously, the attribute of the great teachers, whose influence far exceeds that exerted by their published papers. One

* In honor of this fiftieth anniversary year of the rediscovery of Mendel's law, the Genetics Society of America held a Golden Jubilee Meeting at Columbus, Ohio, September 11–14. On this occasion eminent geneticists of Europe and America were invited to participate. A three-day program of invitation papers traced developments in genetics during 1900–1950. The first paper on the program, by Richard Goldschmidt, was entitled "The Impact of Genetics on Science." Since this address, and the other invitation papers, will be published early in 1951 by the Macmillan Company, no attempt will be made even to summarize the papers here. The book will trace the history of the short life span of the science of genetics, beginning with the rediscovery of Mendel's work and coming down to the present time, with possible glances into the future. It is recommended reading not only for students of genetics but for all those who would be well informed on the accomplishments of this science and on how these results have influenced thinking in other sciences.

of the obvious cases of great teaching combined with brilliant research was, of course, that of Thomas Hunt Morgan. The team of Morgan, Sturtevant, Bridges, and Muller is one of the famous teams of biological investigators. Morgan, with these three graduate students, established beyond question the physical basis of heredity and made Drosophila the important tool it is for genetic studies. An interesting note occurs in the biographical sketch of Calvin Bridges in the 1938 edition of *American Men of Science*: "Private research assistant to Prof. T. H. Morgan, Columbia 1910–15" —a mark of rare distinction. Morgan was awarded the Nobel Prize for his genetic research; the only other geneticist to win the Nobel Prize was one of Morgan's former graduate students, H. J. Muller.

Another of the all-time greats in this class was Edward Murray East. His researches are so familiar as to need no lengthy discussion. His early bulletin (with H. K. Hayes) on *Inheritance in Maize* was the first comprehensive treatise on this subject. His work on inbreeding and crossing maize laid the foundation on which the double cross was built—and this by Jones, a student of East. It was in maize, too, that he discovered, independently of Nelsson-Ehle, the working of multiple factors, thus providing a Mendelian interpretation for quantitative, or "blending," inheritance. East carried on intensive investigations with several species of Nicotiana, and with another graduate student solved the riddle of self-sterility. One of the attributes that made East a great investigator and teacher was his ability to abandon one of his former theories if convincing evidence were presented. This is best illustrated by his studies in self-sterility. While East was in Europe in the summer of 1924, Mangelsdorf developed the theory of an extremely simple series of multiple alleles to explain self-sterility, e.g., S_1, S_2, S_3, etc. This theory was that a plant would only accept pollen of a different constitution than its own. Thus an S_1S_2 plant pollinated by an S_2S_3 individual would accept only the S_3 pollen. When this was explained to me, before East's return from Europe, it seemed one of the cleverest pieces of genetic analysis I had known, and it so impresses me to this day. Mangelsdorf was not sure how East would accept this, since up to that time East was not convinced there could be selective fertilization. The evidence Mangelsdorf presented was thoroughly convincing, however, and they immediately got out a paper regarding it.

In addition to East's brilliant researches, he made an equal, if not greater, contribution to the science of genetics in the first four decades of the present century by his ability to stimulate others. Students came to study with him from all parts of the globe. One of these was Edward F. Gaines, who was one of his most ardent admirers.

Gaines was a product of the Northwest, having grown up in the state of Washington. Spillman's early work on wheat hybrids was familiar to him. (Showcases of Spillman's early researches in hereditary characters of wheat are still on display at Washington State, also a tablet stating that Spillman rediscovered Mendel's laws independently of Correns, De Vries, and Tschermak. This statement is not correct, however. Spillman did make hybrids and obtain exact ratios but did not go any further toward the correct interpretation than several others, notably Naudin, Thomas Andrew Knight, McCluer, and Kellerman and Swingle. Gaines completely made over the wheat varieties of the state of Washington during his career as geneticist and plant breeder during the second, third, and fourth decades of these first fifty years. Starting with varieties largely developed by Spillman, Gaines worked with one primary goal in mind, to develop productive varieties that were resistant to bunt or smut, *Tilletia tritici* (Bjerk) Wint., a disease that was then costing the farmers of the Northwest more than a million bushels of wheat annually, in spite of expensive seed treatment. Through his success in developing smut-resistant varieties and in testing smut-resistant introductions, the disease has been brought under control, largely by the practical application of the science of genetics to plant breeding. Smut-resistant varieties increased in 1919–39 from 18 per cent to 57 per cent of the total wheat grown in the state of Washington, and they have undoubtedly increased even more in the past decade. From 1931 to 1939 the number of cars of wheat grading smutty at the Pacific Coast terminal decreased from 50 per cent to 5 per cent, a remarkable accomplishment of the science of genetics as put to work by a capable plant breeder.

Another great teacher, as well as a competent research worker, was W. E. Castle, of Harvard. His paper on the "Coming of Mendelism" was one of the high lights of the Golden Jubilee program of the Columbus meeting. Castle not only witnessed the coming of Mendelism, but very early became interested in it and has remained actively engaged in genetic research even since his retirement from Harvard several years ago. He now carries on his work at the University of California with undiminished enthusiasm.

One of the early classic experiments in genetics was performed by Castle and one of his graduate students, Phillips. They transplanted ovaries of a black guinea pig into an albino which, when mated

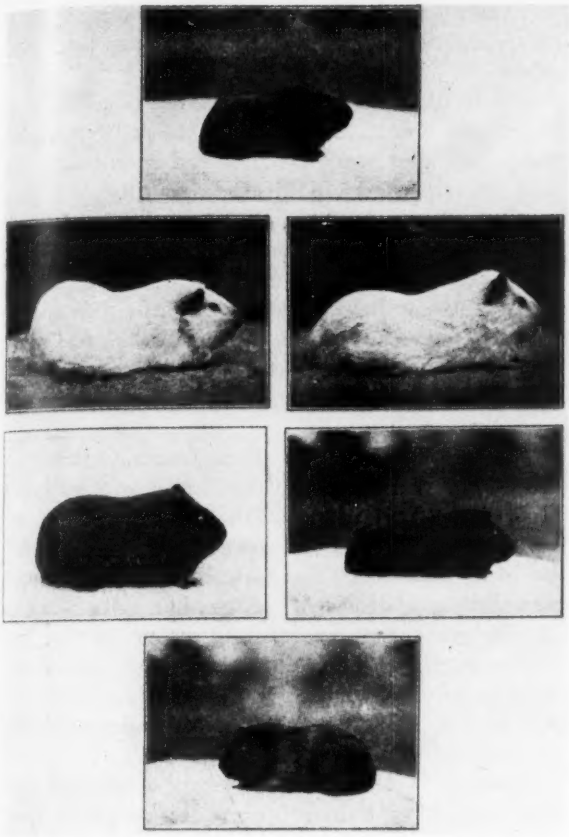

Fig. 1. Transplantation experiments of Castle and Phillips. Ovaries from a small black guinea pig (top) were transplanted into an albino which, mated with another albino, produced black young. (First published in 1911. Reproduced through courtesy of Dr. Castle.)

to an albino, produced an all-black litter, thus providing a dramatic demonstration of the separate entities of the germ plasm and somatic cells (Fig. 1). Castle did his early work at the Bussey Institution of Harvard University and had his influence not only through published papers, but also through the students he attracted to him. His interest and influence extended to students of East as well. The team of Castle, in animal genetics, and East, in plant genetics, was one of the famous combinations for about three decades of the present half century. Another important school where graduate students became genetical investigators was Cornell, under R. A. Emerson. Although several years East's senior, Emerson went from Nebraska to study with East and made important contributions toward the understanding of the inheritance of quantitative characters in maize. Emerson went to Cornell and made it the center for genetic research in the maize plant. His Memoir 39, on *The Genetic Relations of Plant Colors in Maize,* is one of the classics of genetic literature. It records the results of a prodigious amount of work and laid the foundation for much of the maize genetics of this first half-century.

Emerson's sense of humor is evident in this work, an example of which is this paragraph which followed tables of extensive data on the inheritance of plant colors:

> *Relation of aleurone color to plant color.* It is evident from the comparisons already given that the four-factor hypothesis fits well the F_2 data, which is of course to be expected since it was invented for that purpose.

He then went on to show how the hypothesis was substantiated by appropriate breeding tests of future generations.

Although Emerson's work in analyzing the inheritance of color factors, as well as other characters in maize, is monumental, one of his other important contributions to the science of genetics was his stimulation of graduate students and others with whom he came in contact. He was instrumental in establishing the "Maize Genetics Coöperation," an informal organization for disseminating unpublished information about research on maize and for maintenance and distribution of genetic stocks. At every annual meeting of the Genetics Society while Emerson was alive there was a most informal meeting called the "Cornfab," at which the latest information was passed on. The *Maize Coöperation Newsletter,* started by Emerson, is now in its twenty-fifth year and serving a very useful purpose.

One of Emerson's students was Barbara McClintock, one of the few women scientists to be elected to the National Academy of Sciences. It was through McClintock's brilliant researches on cytogenetics in maize that this plant has become such a useful tool in genetic investigations. The development of the pachytene technique, in which all ten maize chromosomes were identified, and the further association of each linkage group with a particular chromosome, was an important milestone in maize cytogenetics, just as was the discovery of salivary gland chromosomes by Painter, and the exhaustive work on associating these with specific genes and chromosomal rearrangements by Bridges and others in the early part of the third decade of the twentieth century.

To the list of Emerson's students should be added the name of L. J. Stadler, who, although not an actual graduate student of Emerson, spent considerable time at Cornell in association with him and his graduate students. He was at Cornell during the summer of 1926 when the International Botanic Congress met at Ithaca. I spent that summer at Cornell working with Randolph on sporocyte preparations and with Stadler on corn pollinations.

There were always lively discussions on the genetics of corn when Emerson, Stadler, McClintock, and other graduate students got together. At one of those discussions I learned Stadler's use of the X-ray to induce mutations in plant material. This work was conceived independently of Muller's, which is so well known as to need no further elaboration here. It is interesting to note that the use of the X-ray as a mutagenic tool was conceived by not one but two separate and independent investigators, just as Mendel's law was confirmed by three such investigators. The use of X-rays for inducing mutations in Drosophila, barley, and maize was one of the big milestones in the first half century of genetics. Both announcements came at the close of the third decade, Muller's in 1927, Stadler's in 1928, although Stadler had X-ray-induced mutations as early as 1925.

The fourth decade of the century proved to be most fruitful for the science of genetics. In 1935, at the St. Louis meeting, there was a demonstration paper entitled "Transplantation in Drosophila," by G. W. Beadle and Boris Ephrussi. This paper outlined the transplantation experiments whereby imaginal discs of various organs, including eyes, were successfully transplanted into other flies. Study of the host-transplant relationship of vermilion and cinnabar eyes gave interesting clues to the chemistry of pigment formation in the eyes; however, the nature of the material did not lend itself to a complete analysis of the chemistry involved. According to a statement Beadle made in his address at the Golden Jubilee meeting, frustration at not being able to go any further with the Drosophila transplantation work led him to consider another organism, *Neurospora crassa.*

This work was reported in an important invitation paper by Beadle and E. L. Tatum at the tenth annual meeting of the Genetics Society in Dallas, Texas, in 1941. Its title was "Genetics of Biochemical Characters in Neurospora," and it ushered in a whole series of experiments on microorganisms. Not only has Neurospora become a standard tool for genetic research, but also some of the lower forms, such as bacteria, are being investigated vigorously and with significant results. Extensive work on Paramecium by Sonneborn and his associates has yielded important results, especially a better understanding of cytoplasmic inheritance. Sonneborn spoke on "The Role of Genes in Cytoplasmic Inheritance" at the Golden Jubilee meeting.

During the past two decades the science of human genetics has also made rapid strides. This progress was outlined by L. H. Snyder in "Old and New Pathways in Human Genetics" at the Golden Jubilee. The rather young American Society of Human Genetics cooperated in sponsoring this program.

Results of the practical application of genetics to plant and animal improvement have been enormous. Although some progress had been made before the rediscovery of Mendel's law, the pace has been greatly accelerated since. Scarcely a cultivated crop has escaped the attention of plant breeders in the general program of breeding for disease resistance. Not only have varieties of wheat resistant to smut been developed, but, largely through the work of Hayes and the Minnesota workers and others, productive varieties resistant to leaf and stem rust have been evolved.

(It should be added parenthetically that the Minnesota school of Plant Breeding is another good example of the influence of one man, H. K. Hayes, far beyond his own researches. Hayes, who went to Minnesota from the Connecticut Agricultural Experiment Station in 1915, has had signal success in the breeding of corn and the other cereals; but we venture to suggest that his biggest success has been in the training of graduate students who have spread the "Minnesota influence" and techniques throughout the world.)

Not only is it necessary to breed for resistance for any particular pathogen, but the plant breeder must be on the alert to develop resistance to different physiological strains of the same organism. And these may change, or mutate, in a manner similar to the way the host plant may change. This is well illustrated by a drawing prepared by H. C. Murphy, who has made substantial contributions to the oat-breeding program in Iowa (Fig. 2).

No summary of the accomplishments of the first half century of genetics would be complete without at least a brief statement about the most outstanding example of the benefit to mankind resulting from the practical application of genetics to plant breeding. I refer, of course, to hybrid corn. More has been written about hybrid corn than about any other agricultural development during the past fifty years. It is not my intention to add much to this lengthy written record. It may be pertinent, however, to give a brief résumé of this agricultural revolution that is so often cited to prove the benefit of pure research in the practical applications of plant breeding. The principal discovery of the isolation of pure lines was made during the course of a research program that had nothing to do with corn improvement, and the "Pure Line Method in Corn Breeding" was announced by G. H. Shull as a result of his research.

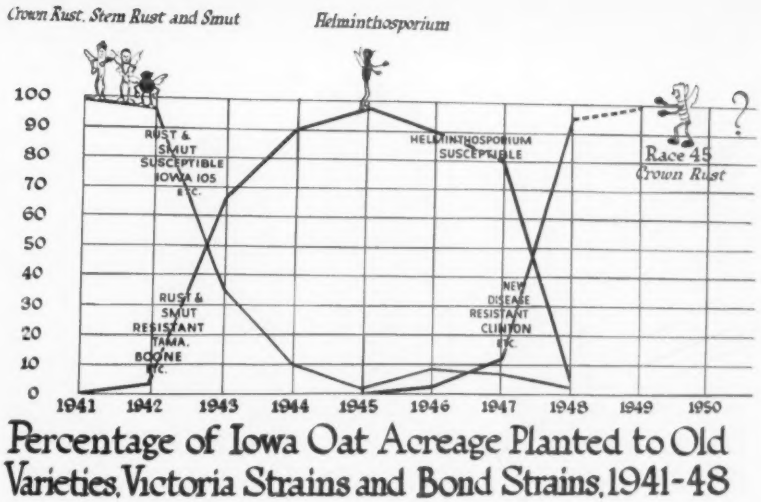

Fig. 2. Chart showing rise and decline of certain oat varieties caused by their resistance or susceptibility to different diseases. (Courtesy of H. C. Murphy.)

A concurrent inbreeding program by E. M. East had produced similar results, but East was skeptical about the use of first-generation hybrids, largely because of the practical difficulties of seed production. However, East's interest in hybrid vigor and his writings on the subject stimulated others to continue the work and to try to produce hybrid seed corn. Hayes continued inbreeding the original lines started by East, and these he turned over to his successor, D. F. Jones, in 1915. It was these lines that Jones used in developing the double cross, which was grown for the first time in 1918.

The development of hybrid corn during the years of World War I is in one way a tribute to th wisdom and farsightedness of Edward H. Jenkins, director of the Connecticut Experiment Station during the war. While other experiment stations were devoting much of their attention to the immediate task of increasing the food supply, Jenkins permitted one of his staff to grow the worthless corn inbreds, whose practical value seemed remote, to say the least. In this case the experiments conducted in World War I paid off handsomely in World War II, when the annual production exceeded three billion bushels. It has been conservatively estimated that the monetary value of the *increased* yield of corn during the war years exceeded two billion dollars, or enough to pay the total cost of the Manhattan Project. Investment in pure research paid big dividends!

Figure 3 is a photograph, never before published, of the original inbred lines of Shull. This illustration shows hybrid vigor between his A and B lines, also considerable hybrid vigor when two sublines of the A inbred were crossed. This photograph was taken several years ago when Shull came to New Haven to address the Northeastern Corn Improvement Conference. Figure 4 shows three men who have had a marked influence on corn genetics and breeding: Jones, Shull, and Stadler. This photograph was made last year at a similar Corn Conference meeting at the Brookhaven National Laboratory.

So much for hybrid corn. What of the future? A number of developments appear possible. Perhaps inbreds may be developed that are sufficiently productive to make single crosses as feasible for field corn as they are for all sweet corn hybrids today. Corn breeders of the future will probably use specific genes more. A good example of this is the waxy hybrid developed by Sprague and others to fill a need for a particular kind of starch cut off during the last war by the cessation of imports of tapioca into this country.

It is possible also that some other genetic type of corn plant may have an important place in future agriculture. A good many short or reduced genes have been discovered recently, and one of these has been incorporated into a number of inbred lines, so that short single crosses and double crosses can be made. There are indications that some of these short types have a higher grain-to-stalk ratio than normal corn and are more efficient in the use of fertilizer. If these preliminary findings are corroborated by more intensive investigations, it may be possible, by the use of the right short gene, to develop a type of corn with a higher grain yield than any yet grown. This is a distinct challenge to the plant breeder. All the grain sorghum grown today is either dwarf or double dwarf, because of one or two recessive genes. These short strains yield as much as the original tall types and are grown because they can be harvested by combine.

Fig. 3. Original inbred lines of Shull. On left, line A maintained by Shull, cross of this by line A maintained by Blakeslee, and line A maintained by Blakeslee. Next ear is cross of line A by line B with line B on extreme right. (Courtesy of George H. Shull.)

With the advent of chemical weed control, and by use of the proper short corn, it may be possible to grow and mature a crop of corn with *no cultivation*. By so doing the corn crop would be divorced from the specified row width and the old row cultivation. Harvesting machinery is already available which, with minor adaptations, could harvest such a crop all in one operation, shelling the grain and returning all the stalks and cobs to the soil. If such a thing seems visionary, well, so did hybrid corn when first proposed. It took years of work and the effort of many workers to make hybrid corn a reality.

I cannot close this article without a statement about atomic energy and how it may be useful in developing improved types of plants and animals. Müntzing in his address at the Golden Jubilee Meeting told how X-rays had developed strains of barley and wheat that gave yields superior to the parent varieties. Everyone is familiar with the story of how an X-ray-induced mutant of penicillium gave a strain with more than double the amount of penicillin of the parent strain.

We venture a guess that radiation produced by atomic energy will be used extensively in developing new types that will be of benefit to man. Gamma rays are similar in their action to X-rays and are already being used to induce mutations and chromosomal changes. A good gamma source is Co^{60}. Beta rays are also being used for internal radiation by feeding the organism with a radioactive β-emitter. P^{32} is a good source of β irradiation. Neutrons from either a nuclear reactor or from a cyclotron are also being used on biological material.

Use of the right source of radiation to induce desired gene changes in material on hand should materially shorten any breeding program. For example, it should be possible to induce a short gene in any inbred corn line, and to detect this mutant in a period of two to three years, whereas it takes ten years to do the same job by crossing and backcrossing.

This is only one of the many ways that atomic energy may benefit mankind, if only man will learn to use this new energy wisely before he destroys himself with it. We do not believe this is imminent, and we look forward with confidence to great ac-

complishments in the science of genetics in the coming fifty years. Perhaps the next half century will solve the riddle of what the gene really is and how it accomplishes its wonderful feats. If that occurs, the year 2000 will be an occasion for real celebration.

Fig. 4. Three important figures in maize genetics and breeding. Left to right, they are D. F. Jones, G. H. Shull, and L. J. Stadler.

Rocket Research in the Twentieth Century

JOSEPH W. SIRY

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ROCKETS have been known for more than seven hundred years, yet rocket research in the modern sense was still in its infancy when the twentieth century dawned. The earliest rockets were weapons. Later they were largely displaced as military items by guns, and different uses were found for rockets. Displays of rockets and other pyrotechnics have been used to lend a festive air to celebrations for at least three hundred years. Toward the end of the eighteenth century, war rockets reappeared in India in the hands of native troops engaged in fighting the British. The effectiveness of these missiles stimulated Colonel William Congreve to develop more powerful versions in England. These rockets, and similar models brought forth by other Western countries, were prominent on the battlefields of the Napoleonic era. About one hundred years ago rockets again were superseded as weapons by artillery. As before, however, the rocket did not disappear from the scene entirely, for it was adapted to serve other purposes.

The rockets of 1900 were basically not very much different from those developed centuries earlier. They were powder-fueled missiles, similar in many respects to the familiar types still fired on the Fourth of July. The modern era of rocket research had scarcely begun at the turn of the century. A fundamental change was wrought in the conception of the rocket at about this time. Serious consideration began to be devoted to the rocket as a possible means for conducting scientific experiments at very high altitudes, and ultimately as a vehicle for space travel. R. H. Goddard and K. E. Ziolkovsky were among the first to apply modern scientific methods in an effort to achieve the realization of these dreams.

Ziolkovsky, a Russian mathematician, published a number of articles relating to rockets and space travel at the beginning of this century. In them he detailed proposals for a regeneratively cooled rocket motor employing a De Laval exhaust nozzle. He saw the theoretical advantages of propellant combinations consisting of liquid oxygen and either a liquid hydrocarbon or liquid hydrogen. Goddard thought along similar lines; however, he complemented his theoretical studies with experimental investigations. His work in the laboratory and on the proving ground inaugurated the modern era of rocket research.[1, 2]

Goddard's early theoretical calculations indicated that the rocket would be a valuable upper-atmosphere research tool provided that sufficiently large values of the mass ratio and exhaust velocity could be achieved. The crucial role played by these parameters can be appreciated more readily by considering some of the principles that govern rocket performance. The rocket motor is a reaction engine consisting of a combustion chamber and an exhaust nozzle through which the gaseous combustion products flow from the rocket. The momentum of the escaping gases is balanced by a corresponding change in the momentum of the rocket, and it follows from Newton's laws of motion that the thrust, or force, exerted by the motor is equal to the product of the mass flow rate, w, and the effective exhaust velocity, c, of the jet gases.

St. Venant evidently was the first to realize that in an isentropic flow the velocity at the throat of a convergent nozzle cannot exceed the local speed of sound, and that a convergent-divergent nozzle is necessary if supersonic velocities are to be attained. He made this discovery in 1839. Almost half a century later De Laval put the idea into practice in designing steam turbine nozzles, and his name has since become associated with this type of nozzle. Goddard applied the same key notion in the construction of his rocket motors.

The importance of this step can be seen by ap-

plying Newton's second law of motion to the case of a rocket in vertical flight to obtain:

$$ma = wc - mg - D, \qquad (1)$$

where m and a are the rocket's mass and acceleration, respectively, g is the gravitational acceleration, and D represents the retarding force of atmospheric drag. The variation of D with time cannot be conveniently represented analytically and, in fact, is not always accurately known throughout the region of interest. Nevertheless, many of the essential features of rocket flight can be understood by considering the simplified case in which it is assumed that D is negligible and w, c, and g are constants. The velocity and height at the end of powered flight can be obtained from equation (1) by quadratures, and the maximum altitude, h, is given by

$$h = \frac{c^2}{2g}\left[1n(1-b)\right] + ct\left[1 + \frac{1}{b}\,1n(1-b)\right], \qquad (2)$$

where the initial velocity and altitude are zero, t is the duration of the propulsion period, and the propellant mass ratio or the propellant bulk ratio, b, is defined as the ratio of the mass of propellants expended during burning to the total mass of the rocket at take-off. The peak altitude reached by a large, high-altitude rocket is usually determined primarily by the value of the first term of equation (2). This term is proportional to the square of the effective exhaust velocity, c, and also increases very rapidly with b as b approaches unity.

Goddard's experiments were the first in which the mass ratio and the exhaust velocity received due consideration. His first step was to increase the exhaust velocity about eightfold, to almost 8,000 feet per second, by burning more powerful solid fuels at higher chamber pressures and by allowing the gases to exhaust through a De Laval nozzle.

Goddard's approach to the mass-ratio problem was essentially the same as the one employed today, that of using separate housings for fuel storage and fuel combustion. In this way only the relatively small motor chamber must be constructed so as to withstand the high temperatures. When liquid propellants are employed, the tanks can also be operated at relatively low pressures by utilizing fuel pumps. These measures can effect considerable weight savings and thus make possible higher mass ratios.

Goddard began to apply these principles by developing a mechanism for reloading his small, solid-fuel rocket motors automatically. This work was started in 1917 under a grant from the Smithsonian Institution and continued as a wartime project. During the war he also developed a predecessor to the "Bazooka," a device that was to play such a vital role as an antitank weapon a generation later.

The First Liquid-Fuel Rocket

In 1920 Goddard began a series of experiments with liquid fuels under a grant from Clark University, where he was then professor of physics and director of the Physical Laboratories. The world's first liquid-propellant rocket (Fig. 1) was launched by Goddard on March 16, 1926. This historic event took place at Auburn, Massachusetts, on the farm of a relative of Professor Goddard's.

The tests continued there until July 17, 1929, when neighbors mistook a rocket flight for an airplane crash. The publicity and alarm generated by the incident made it necessary to remove much of the experimental apparatus to the artillery range at near-by Camp Devens. Various methods for injecting fuel and cooling the combustion chamber were tested there during the next year. Goddard developed the film cooling principle and a variation of

FIG. 1. Professor Goddard and the world's first liquid-fuel rocket in its launching frame. The first flight was achieved on March 16, 1926.

regenerative cooling technique during this period. He obtained effective exhaust velocities of well over 5,000 feet per second. The commotion that had accompanied the flight of July 17, 1929, was not without its happier side, for it brought the work to the attention of Daniel Guggenheim, who agreed to finance the studies for a two-year period. The nature of his grant was such that it became possible to transfer operations to an ideal location near Roswell, New Mexico, within V-2 range of the present White Sands Proving Ground! Goddard's modest research installations soon developed into a small-scale model of the White Sands establishment, complete in almost every detail. The similarity did not end there, however. A number of the fundamental principles employed in the rockets that are now fired at White Sands were first developed and tested by Goddard.

The rocket seen in Figure 2 was flown at the new site on April 19, 1932. It bore more than a superficial resemblance to the present-day missile of the V-2 type, for it was the first to be equipped with a modern control system. It was steered by means of a gyroscope and four pairs of air and jet vanes. Many of the principles and techniques employed in this rocket were later used in the German V-2.

The depression interrupted the New Mexico program in 1932, and Goddard returned to Clark University. While there he began the development of rocket fuel pumps and devised an apparatus that was the forerunner of the modern ramjet.

Goddard returned to New Mexico in 1934, and the flight-testing program was resumed. He was more concerned with developing sound principles and procedures than with the actual building of a spectacular, record-breaking rocket employing all the refinements available at the moment. Nevertheless, he did establish some records. For example, the rocket launched on May 31, 1935, rose to a height of 7,500 feet, the highest altitude ever reached by a rocket up to that time.

Goddard's emphasis upon fundamentals bore fruit again in the rocket tested on July 28, 1937. This missile was steered by appropriately altering the direction of the axis, and hence also of the thrust, of the rocket motor. This same control principle is now employed in the Viking, the Navy's new upper-atmosphere research rocket.

In the years from 1938 to 1941 Goddard developed several different types of fuel pumps. Some were driven by gas generated in a small auxiliary combustion chamber that burned the primary rocket fuels. Others were powered by gas drawn directly from the main combustion chamber. Still others utilized gas generated by the evaporation of liquid oxygen in a copper tube jacket surrounding the rocket motor. A jacket of this type is visible in Figure 3. Some idea of the size and complexity of the rockets developed by Goddard in this period can be gained from Figure 4. The rocket shown there was almost 22 feet long and weighed 500 pounds when ready for flight. More than half the take-off weight consisted of propellants.

FIG. 2. First rocket to incorporate a modern control system shown before its first flight test on April 19, 1932. Dr. Goddard is second from the right.

During World War II Goddard conducted confidential rocket research at the Naval Engineering Experiment Station at Annapolis. It was his plan to resume the work in New Mexico as soon as hostilities ceased. His death on August 10, 1945, brought

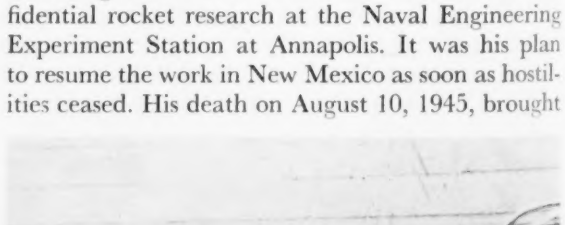

FIG. 3. Motor assembly of the rocket tested by Goddard on November 18, 1939.

an untimely end to one of the outstanding careers in the history of rocket research. When Goddard turned his hand to the subject in the early years of the century, rockets were relatively simple, powder-fueled devices. In less than a generation he developed rockets that were the archetypes of modern vehicles such as the V-2 and the Viking. He was not always the first to propose innovations but, in many important instances, he was the first to translate the dreams and ideas into actual working models. The wealth of research material which he left has not yet been fully utilized.

Goddard's pioneering development of the modern rocket had begun in earnest shortly before World War I. For more than a decade he was almost alone in the field. Interest in rockets gradually became more widespread, however, and during the postwar period it crystallized when rocket societies were formed in a number of different countries. Notable among them were the *Verein für Raumschiffahrt* ("Society for Space Travel," often known by the initials VfR), founded in Germany in 1927, and the American Interplanetary Society, now known as the American Rocket Society, founded in Manhattan in 1930.

Goddard was reticent concerning his progress during this period, and communication among the various other groups, although sometimes enthusiastic, was nevertheless haphazard. As a result, many of the major advances were independently rediscovered or retested several times. For example, the technique of cooling the rocket motor by passing one of the liquid fuels through an enveloping jacket was proposed by Ziolkovsky at the beginning of the century and, also, after World War I, by Oberth. Experimental attempts to exploit this principle were made by Goddard in Massachusetts in the first half of 1930.[2] The method may also have been used during this period by Max Valier in his rocket car experiments conducted at Berlin.[3,4] Two years later, after having tried a number of water-cooled models, the Verein für Raumschiffahrt tested a liquid-oxygen, alcohol motor cooled by a fuel jacket.[3] In 1933 Eugen Sänger, of the Technischen Hochschule at Vienna, also experimented with a motor cooled in this way.[5] His model used Diesel oil and liquid oxygen. The regeneratively cooled motor evolved still another time in 1938 in the work of the American Rocket Society.[6] Thus the early development of the liquid-fuel rocket involved a certain amount of duplication and repetition of some phases of the research.

Special interest attaches to the work of several groups, neverthless, in view of the fact that their early experimenal models were the progenitors of the rocket motors found in such important modern achievements as the V-2, the Aerobee, and the Viking. In point of time, the first of these new rocket research centers grew up in the Old World.

European interest in the subject received a new stimulus in 1923 with the publication of Oberth's *Die Rakete zu den Planetenräumen* ("The Rocket into Interplanetary Space"). The book dealt with the main features and some of the details of rocket flight. It was soon followed by a number of other publications relating to rockets. The cosmopolitan character of the subject was accorded recognition in 1928 when the International Astronautical Award was established under the auspices of the Société Astronomique. The prize became known as the REP-Hirsh Award, after the donors, Robert Esnault-Pelterie, a pioneer in aviation, and André Hirsh, a Paris banker. It was to be given annually for the outstanding piece of research in the field of space travel. The first award fell to Oberth in 1928 for his treatise *Wege zur Raumschiffahrt* ("Road to Space Travel"). Oberth's works contained a number of prophetic ideas in addition to the one for the use of regenerative cooling. He also proposed the application of film cooling, and the use of liquid oxygen and dilute ethyl alcohol as fuels.

In 1929 Oberth directed the development of a rocket which was to have been launched at the premiere of the film *Frau im Mond* ("The Girl in the Moon"). Fritz Lang, the director, and the UFA Film Company, the producer, provided the funds for the necessary rocket research. It was planned to fire the missile for publicity purposes in order to heighten interest in the motion picture, which was built around a fanciful rocket trip to the moon. Oberth conducted experiments with liquid air and gasoline and designed the *Kegeldüse,* the name deriving from the conical shape of the rocket motor nozzle. As time grew short he turned to a somewhat simpler design employing a nose drive and using carbon and liquid oxygen as fuels. Neither of these versions was completed in time for the

FIG. 4. Internal arrangement of the November 18, 1939, rocket.

premiere, but the affair did help to transform the VfR from a literary and debating society into an organization with an active experimental program.[3]

The VfR and the Raketenflugplatz

Work was begun by a small nucleus of the membership, which then totaled almost a thousand. At the outset the philosophy of the new group was similar to Goddard's. The first attempts were aimed at producing an operable liquid-fuel rocket which was to be of the smallest possible size in order to conserve funds. It was called the *Minimumrakete,* which was soon abbreviated to "Mirak." Rudolf Nebel, who had worked with Oberth in the abortive *Kegeldüse* development, proposed the Mirak idea and built the first model. The influence of the powder rocket was clearly evident in the first Mirak's appearance. The liquid-oxygen tank formed the head of the rocket, and gasoline was carried in a long slender container which occupied the position traditionally assigned to the guiding stick. The motor, a small model of the *Kegeldüse,* was located in the base of the oxygen tank. Thus the liquid oxygen served also to cool the combustion chamber. The first Mirak was tested by Nebel and Klaus Riedel on a farm owned by Riedel's grandparents. The rocket exploded during one of the experimental runs. The VfR's initial attempts were reminiscent of Goddard's early trials. Like Goddard, the VfR set up shop in a new location in 1930. Instead of choosing a site in a remote section of the continent, however, the VfR established its *Raketenflugplatz* ("rocket airdrome") in Berlin.[3]

The second Mirak was tested there. It, too, exploded during one of the static tests. This was evidently because the heat generated by the motor was greater than could be safely dissipated in the liquid oxygen. In the ensuing emphasis on motor development, water cooling was used in test stand runs and in some of the early flights. The VfR's first flight test occurred in May 1931. Riedel played a prominent role in this phase of the work.

In an effort to avoid the connotation of the powder rocket, the VfR's early flying models were styled "Repulsors." The first of these were referred to as "Two-Stick Repulsors," the sticks being the fuel tanks, as in the case of the Miraks. The powder rocket terminology was persistent! Various arrangements, including a one-stick version, were tried, and a number of successful flights were made. The One-Stick Repulsors attained altitudes of about a mile in the late summer of 1931.

They were capable of even greater heights, but the *Raketenflugplatz* was not large enough to permit such flights with safety. A similar inadequacy had plagued Goddard in Massachusetts and persists even today at such giant ranges as the White Sands Proving Ground. The VfR had its share of ill luck in this connection. One of the rockets landed on a shack and set the roof afire. The structure was an old one, but it happened that it belonged to the police. It is easy to imagine the trouble that followed. The VfR was able to establish, however, as Goddard had several years before, that the launching of rockets can be made reasonably safe if proper precautions are observed.

Several larger motors were developed, including the regeneratively cooled, liquid-oxygen, alcohol motor referred to earlier. The latter, when tested in the spring of 1932, developed a thrust of a little more than 130 pounds.

The deepening economic depression and the schisms within the VfR that accompanied Hitler's ascendancy had an atrophic effect upon the research program. The gradual decline was climaxed when the Gestapo seized the files and dispersed the remnants of the *Raketenflugplatz* personnel.

The VfR had done yeoman service in the cause of the liquid-fuel rocket in a little more than a year of intensive work at the *Raketenflugplatz.* More than one hundred flights had been made, and about three hundred static tests of rocket motors had been made. These results had been achieved on what amounted to shoestring resources, consisting of VfR membership dues, larger donations from an occasional wealthy sponsor, and the ingenuity of the indefatigable *Raketenflugplatz* staff. Almost the entire machine shop and material stockroom were assembled by contributions from industrial firms. These were made in response to hundreds of letters from the VfR asking for items which the firms could not use but which might be of value to the rocket research program. A similar letter even resulted in a waiver of the gasoline tax, which then amounted to more than five sixths of the retail price. In addition, static test demonstrations were staged for engineering societies for a fee, which was usually about 200 marks.

Ironically, the one really large sum to be allotted to the work at the *Raketenflugplatz* came just after the original group had begun to disintegrate. The city of Magdeburg, whose burgomaster, Otto von Guericke, had conducted the celebrated experiment with evacuated hemispheres in the seventeenth century, was anxious to continue its scientific tradition. Nebel was offered 25,000 marks to develop a man-carrying rocket to be launched as the climax of a special city holiday in June 1933. Actually, a smaller rocket, not designed to carry a passenger, was constructed, and the firings suffered the usual mishaps.

The work did produce a larger motor, which developed a thrust of up to 440 pounds. After the disappointing Magdeburg celebrations, the rocket group built a Four-Stick Repulsor around the new motor. It stood 7½ feet high. Figure 5 shows such a Four-Stick Repulsor, one of the last rockets to be made at the *Raketenflugplatz*.

European rocket activity during this period was not concentrated entirely at the *Raketenflugplatz*. Actually, the first liquid-fuel rocket to be flown successfully in the Eastern Hemisphere was launched by Johannes Winkler, who had preceded Oberth as president of the VfR. It took off on March 14, 1931, almost five years after Goddard's first flight. It was a small rocket, about 2 feet long and weighing eleven pounds; nevertheless, it attained an altitude of approximately 2,000 feet. Winkler used liquid methane and liquid oxygen as fuels. A month later a 350-pound thrust motor was demonstrated in a rocket car. The propulsion unit had been designed by Alfons Pietsch, who continued Valier's work after the latter was killed by an explosion of one of the previous models. The motors used in these rocket car experiments were evidently of the regeneratively cooled type.

Interest in powder rockets continued during this period. Reinhold Tiling conducted tests with his winged powder rockets in the spring of 1931. Flights of powder-fueled mail rockets were staged in several parts of the world during the decade that preceded the second world war. The existence of this widespread and growing interest in rockets quite naturally drew attention in military circles. The German Army set aside a portion of its artillery proving grounds at Kummersdorf for powder rocket research under Captain Walter Dornberger. In the fall of 1932, after witnessing a highly successful demonstration flight of one of VfR's One-Stick Repulsors, army officials widened the cognizance of Dornberger's unit to include liquid-fuel rocket studies. This event occurred at the time that the VfR had begun to collapse, and some members of the *Raketenflugplatz* personnel, including von Braun and Riedel, joined the staff of the new research group.

Their first rocket, which had the code name Aggregate No. 1, or A-1, was built in 1933. It was redesigned, designated the A-2, and flight-tested in 1934 at the island of Borkum in the North Sea. Powered by a liquid-fuel motor delivering a 660-pound thrust, it reached an altitude of 6,500 feet. The rocket was stabilized directly by means of a large gyroscope. The A-2 was about a foot in diameter, 55 inches tall, and weighed approximately 330 pounds at take-off. This included the stabilizing gyroscope, which weighed about 90 pounds, and approximately 90 pounds of fuel.

Peenemünde and the V-2

Larger motors were developed, and the program soon outgrew the facilities available at Kummersdorf. The Baltic coast provided the only suitable location for a large rocket firing range. Accordingly, an obscure insular location at the village of Peenemünde was selected as the site for the new research establishment. Construction was begun in the summer of 1936. The Air Force had entered the picture by this time; as a result, the work was divided, and two separate stations were built, Peenemünde-Ost, for the Army, and Peenemünde-West, for the Air Force. The ultimate cost of the entire establishment was about $75,000,000.

The scale of operations at Peenemünde was reflected in its first product, the A-3, which was 25 feet long, 30 inches in diameter, and weighed 1,650 pounds. The motor developed a thrust of 3,300 pounds and operated for 45 seconds. The A-3 resembled the V-2 both in appearance and in the fact

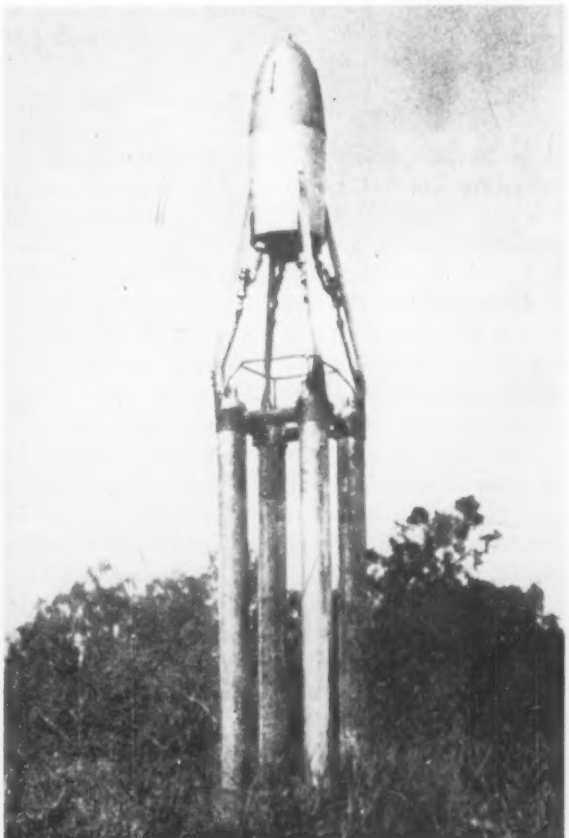

FIG. 5. A "Four-Stick Repulsor" at the *Raketenflugplatz*. This was one of the last models designed by the *Verein für Raumschiffahrt*.

that it incorporated an automatic control system. Steering was accomplished by means of jet vanes. Flight tests of the A-3, and a similar model designated A-5, were conducted in 1938. Altitudes of 40,000 feet were attained with these missiles. The results indicated that the development of a long-range rocket would be feasible.

A large supersonic wind tunnel was put into operation at Peenemünde in 1939. When data from this instrument became available, the design and construction of a much larger rocket were undertaken. The first flight test of the new model, the *Fernrakete* A-4 ("long-range rocket A-4"), took place on July 6, 1942. The rocket reached an altitude of one yard and then exploded. The second A-4 reached an altitude of 3 miles before it exploded. A successful flight was not achieved until the fourth A-4 was fired on October 3, 1942. The performance of the fifth A-4 was probably satisfactory, although this is not certain since the impact was not located. The next thirteen A-4s were failures. Some exploded, others broke in two, none flew as intended. These difficulties were gradually overcome in the next hundred firings. Even at the end of this period of development, however, 15–20 per cent of the A-4s were failures.

The losses which the Nazi bomber fleets experienced at the hands of British fighter squadrons hastened the decision to begin large-scale production of the less vulnerable A-4. The order was given only a few months after the first successful flight test. Many of the A-4's shortcomings still remained to be remedied when the *Waffen-SS* took control of the program following the attempt on Hitler's life on July 20, 1944. Nevertheless, it was only a few weeks later that the first A-4 was launched against London as *Vergeltungswaffe Zwei* ("Revenge-Weapon Two"), or, simply, V-2.

This rocket[3,7] was 46 feet tall, had a maximum diameter of 65 inches, and weighed more than 14 tons at take-off. It consumed almost 10 tons of propellants during powered flight, which lasted slightly more than a minute. The motor had an effective exhaust velocity of about 6,500 feet per second and delivered a thrust of 28 tons at sea level. The V-2 was capable of carrying a one-ton warhead to an altitude of a hundred miles or to a range of about 200 miles.

A number of the *Raketenflugplatz* and Kummersdorf personnel had eventually become associated with the program at Peenemünde. At the close of the war, Dornberger, then a major general, was in charge of all rocket development in Germany. Von Braun was technical director of the V-2 development. Oberth, whom von Braun recognizes as "the father who inspired our thought,"[8] encountered difficulties in actually coming to Peenemünde. At first Oberth was caught in the web of interservice rivalries. The V-2 was an army project. In 1938, the *Luftwaffe* engaged him in an attempt to foster a rival development at the Technischen Hochschule, Vienna. Later this plan was abandoned and his services were offered to the army. He was a native Transylvanian, and still a Rumanian citizen, however, and therefore was not admitted to the top-secret confines of Peenemünde. When he finally arrived at Peenemünde after obtaining German citizenship, he found that his brainchild, the V-2, was already in being. One can well imagine his feelings when he first witnessed the realization of his dreams of two decades before.

Some of Oberth's ideas had appeared in the work of the VfR. In many ways, however, the V-2 bore a closer resemblance to Goddard's rockets than it did to those which were tested by the VfR at the *Raketenflugplatz*. It was similar to Goddard's developments in that it had the same general arrangement, both internally and externally. Its control system used the gyroscope as a sensing element, and air and jet vanes for steering. It relied upon fuel pumps, and fuel was injected at the head of the combustion chamber, rather than in the neighborhood of the exhaust nozzle. The actual devices employed in the V-2 differed in some features from those used by Goddard. For example, the carbon vanes of the German rocket lay continually in the region of the exhaust jet, where they acted as rudders. In some of Goddard's rockets, on the other hand, portions of the jet were deflected by the vanes only when corrective forces were being applied. The V-2 fuel pumps were powered by a steam turbine which employed an auxiliary fuel, hydrogen peroxide, whereas Goddard developed a number of ingenious methods for utilizing the energy of the primary rocket propellants to drive the fuel pumps.

The primary fuels of the V-2 were liquid oxygen and a mixture of alcohol and water. The water was added as a coolant to supplement the action of the regenerative and film cooling systems which the V-2 employed. Here, again, the design of the V-2 was foreshadowed in the writings of Oberth and in the rockets of Goddard.

The chief significance of Peenemünde from the rocket research standpoint lay in the fact that there for the first time a modern, large-scale, coordinated rocket research and development effort was undertaken. The innumerable problems were attacked by many teams of specialists, who had the necessary facilities placed at their disposal. They trans-

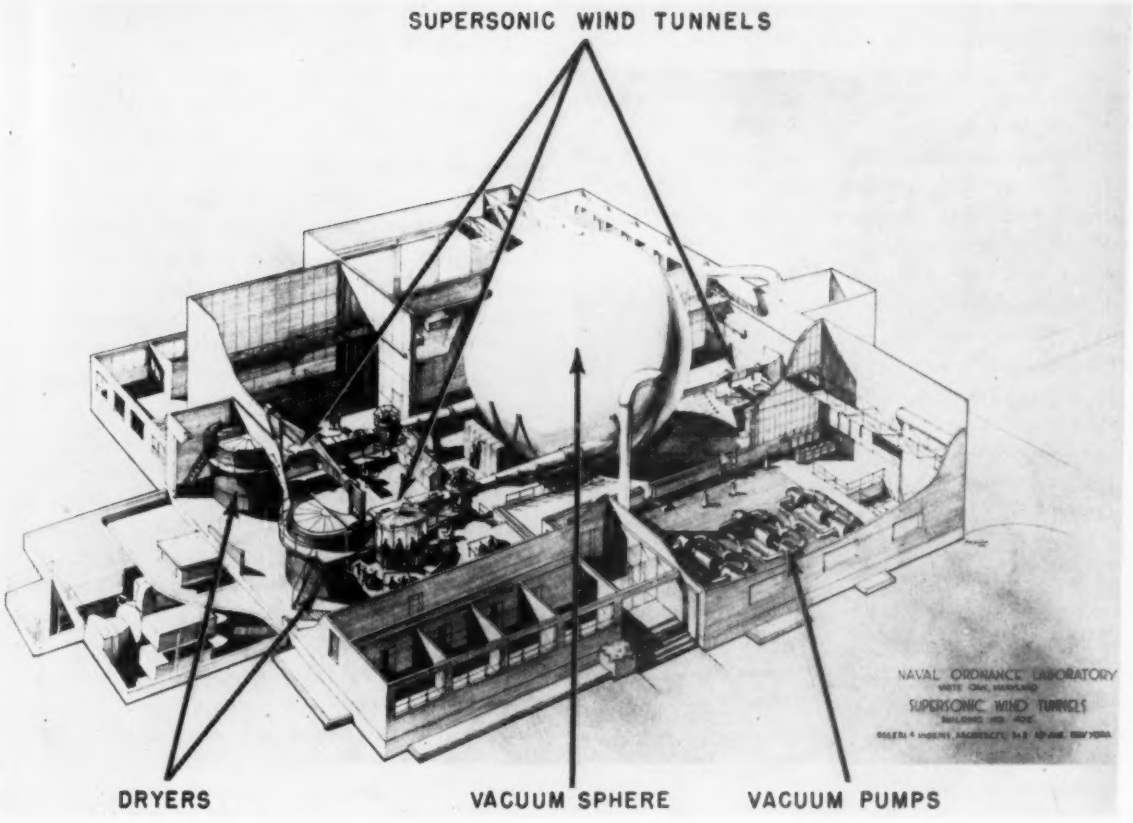

FIG. 6. The supersonic wind tunnel installation at the Naval Ordnance Laboratory, White Oak, Maryland.

lated the basic ideas and inventions, many of which had been discovered elsewhere, into a high-performance rocket of unprecedented size. The missile was adapted for mass production, and the handling and firing operations were reduced to a routine. The decade and a half from the *Kegeldüse* to the V-2 was truly an epoch in the history of rocket research.

The V-2 program apparently did not receive any unusual priorities. In fact, Hitler was reportedly opposed to it, having dreamed that the rocket could not fly. After the V-2 became a production item, the growing offensive power of the Allied air forces caused Peenemünde's principal effort to be diverted to the development of a guided antiaircraft rocket known as the *Wasserfall*. The RAF struck a more direct blow at the further development of the V-2 on the night of August 17, 1943, when a full-scale bombing attack was launched against Peenemünde. Among the hundreds who lost their lives were a number of key personnel.

Early in 1944 the large supersonic wind tunnel installation was moved from Peenemünde to Kochel, Bavaria, where it was captured by American forces the following year. It was dismantled, improved, and re-erected in the Naval Ordnance Laboratory at White Oak, Maryland, a suburb of Washington, D. C. (Fig. 6).

The tunnel's basic principle of operation is simple. Dried air is allowed to enter a large, evacuated sphere through a De Laval nozzle. This method has been used at White Oak to develop speeds greater than six times the local velocity of sound in a 40-centimeter working section. Flows in the neighborhood of ten times the local sonic velocity have been generated in a smaller research tunnel. During the first world war the French used a variation of this technique to study the aerodynamics of high-velocity artillery projectiles.

Before it was captured, the Kochel wind tunnel was being utilized to further the development of the V-2. The range of the rocket was increased considerably by the addition of a pair of wings, which enabled it to glide as it re-entered the denser portions of the atmosphere. This modified version of the V-2, seen in Figure 7, was known as the A-9. A range of 300 miles was evidently achieved with a rocket of this design.

Proposals were drawn up for the development of a booster rocket, designated A-10, which was in-

tended to be used in conjunction with the A-9. The A-9, A-10 combination was planned as a two-stage rocket. The total take-off weight of the pair was to be more than a hundred tons, and the thrust of the A-10 was to have been over 200 tons. The range of this monster was calculated to be in excess of 3,000 miles. The preliminary investigations for its development had been completed when Allied troops reached the laboratories.

Plans had been laid for the use of this "America Rocket" as a bombardment weapon, and the target had already been selected. It was marked on a document found in Goering's files by intelligence officers after V-E day. The aiming point was near Broadway, midway between the twin clusters of giant skyscrapers which stand as the unique hallmark of the world's largest city. Fortunately, this teratoid product never reached its mark.

FIG. 7. A photograph of what might have become the first trans-Atlantic rocket. This winged V-2 was to have been the smaller part of a giant, 100-ton, two-stage rocket intended for bombarding America from bases in Europe.

The American Rocket Society

A number of years earlier the film *Frau im Mond,* a quite different product of the German interest in rockets, actually did arrive in Manhattan, where it played a part in the story of rocket research in the United States. In an effort to stimulate a more widespread interest in rockets in general and in itself in particular, the newly formed American Interplanetary Society sponsored a public meeting in the auditorium of the American Museum of Natural History. The program featured an address by Esnault-Pelterie, who was visiting New York, and a showing of the rocket scenes from *Frau im Mond.* The response gave evidence of a considerable interest in the subject. The auditorium was filled, and an overflow crowd of more than a thousand persons waited outside for two hours on a January night to attend the second performance of the program. Unfortunately, Esnault-Pelterie had fallen ill and was unable to appear in person. His address was read by G. Edward Pendray, vice-president of the society. This event served to launch the new organization and gave strong impetus to its growth.[6]

Pendray visited the *Raketenflugplatz* later in 1931, and upon his return a research program was begun. Static tests of rockets and rocket motors were made at a number of different suburban locations in New Jersey and Westchester. Flight tests were conducted on the Staten Island shore of Lower New York Bay (Fig. 8). The early work was similar in many respects to that of Goddard and the VfR. The first rocket flown by the American Rocket Society is visible in Figure 8. The motor was mounted at the forward end, and the fuselage was of the two-stick variety. Even many of the colorful experiences were repeated once again. The society's first static test was conducted on a farm, this time in New Jersey. An account of one of the later experiments noted that "numerous local inhabitants were drawn to the scene by the roar of the first motor. They were fearful that an airplane had crashed in the valley. . . . Midvale police chief investigates strange sounds among Jersey hills."[9]

The group's principal flight occurred on September 9, 1934, when a speed of about 700 miles per hour was attained by a rocket designed by John Shesta. The cast aluminum motor and the fuel tanks were collinear, the motor being mounted above the tanks. The jets issued from four nozzles in directions that made angles of 20 degrees with the missile axis. During the flight the motor burned through at an altitude of about 300 feet, and the rocket began to turn downward. The motor was still operating when the rocket entered the water

of the Lower Bay a quarter of a mile from the launching rack.

In 1936 the first International Astronautical Award to honor American work was given *ex aequo* to the American Rocket Society and to Alfred Africano, one of its members. The award was made not only for the "careful experiments,"[10] but also because the society gave its results "extensive publicity by means of its journal *Astronautics*." Many of the American Rocket Society experimenters were in a position similar to that of Africano, who was employed as a research engineer by the New York subway system and pursued his rocket studies as an avocation. In announcing this award of the REP-Hirsh Prize the Société Astronomique expressed "its keen regret that a very important work of Professor Goddard arrived so late that it was impossible to give him the reward which he merited for the exceptional value of his achievements."[10]

James Wyld's design for a regenerative motor was published in *Astronautics* in 1938, and the motor was first tested in December of that year. It produced a thrust of more than 90 pounds and a jet velocity of 6,000 feet per second.[6] More powerful motors followed, and on the Sunday that Germany invaded Russia a motor designed by Africano registered a thrust of over 260 pounds.

In 1941 four members of the society formed a corporation to develop rocket propulsion equipment for the armed forces. The company, known as Reaction Motors Incorporated, has conducted its research operations at several locations in New Jersey on the periphery of metropolitan New York. During the war RMI developed rockets for use in jet-assisted take-off applications.

Active interest in rockets had meanwhile spread to other parts of the United States. A rocket research program was begun in 1936 at the Guggenheim Aeronautical Laboratory of the California Institute of Technology. The experimental work of the GALCIT group was integrated with an exceptionally fruitful theoretical program. In 1940 the Jet Propulsion Laboratory was established at the California Institute of Technology. This rocket research center underwent considerable expansion during the war.

American rocket research in World War II began in the summer of 1940.[11] Goddard had previously tried without success to interest the armed services in the military possibilities of rockets. It remained for one of his former students, C. N. Hickman, then associated with the Bell Telephone Laboratories, to galvanize this country into action in the field of rocket research. Hickman had assisted Goddard in

FIG. 8. First rocket flown by the American Rocket Society. The launching took place on May 14, 1933, at a Staten Island beach on Lower New York Bay.

World War I in the development of military rockets, and he was aware of their potentialities. His success in arousing interest may have been partly due to his timing. It was during the fall of France, two days before the second armistice was signed at Compiegne, that he brought the possibilities of rockets to the attention of F. B. Jewett, who was president of the Bell Telephone Laboratories and also chairman of a division of the National Defense Research Committee. Jewett submitted Hickman's proposals to appropriate governmental agencies. The response was the establishment of Section H in Division A of NDRC. Other units subsequently were formed under NDRC. The California Institute of Technology provided the nucleus of the principal rocket research center that came under this program. This center grew rapidly, and by 1944 it was staffed with more than 3,000 employees. Work was also done at a number of other institutions, including the Allegany Ballistics Laboratory, in western Maryland, which was operated by George Washington University. Almost 100 million dollars was expended for rocket research under NDRC during the war. At the close of the conflict the Navy alone had more than 1,000 war plants producing rockets, at an annual rate of well over a billion dollars.

Rockets were employed by most of the combatants in a wide variety of tactical and strategical situations. The Bazooka enabled the infantryman to defend himself effectively against the tank. The tank itself was sometimes equipped with elaborate rocket barrage apparatus. Many General Sherman tanks mounted a rapid-fire launcher known as the "Calliope," which had a capacity of sixty 4.5-inch rockets. Rockets were used to lay smoke screens, and to hurl incendiary bombs. They were employed at sea in antisubmarine warfare. Amphibious operations were supported by rocket boats. These

were light craft capable of approaching close to the invasion beach, and laying down an intense barrage during the crucial interval between the cessation of the naval gunfire and air bombardment and the first landings.

Rockets also were used both offensively and defensively in aerial warfare. Aircraft were equipped with rockets ranging in size up to the "Tiny Tim," a missile which was over 10 feet long and weighed more than half a ton. Antiaircraft rockets were used in the defense of Britain. Rocket propulsion was used as the main source of motive power in very high speed fighter aircraft such as the Messerschmitt *Komet*. It was also widely used for jet-assisted take-off.

Solid-fuel rockets enjoyed a renaissance during World War II. This was due in part to the fact that they could be manufactured more readily and rapidly than liquid-fuel rockets, which required separate fuel tanks, special fuel pumps, or pressurizing apparatus, etc. Solid-fuel rockets were also, in many ways, simpler and safer to handle and operate under battle conditions. Most of the rockets used in World War II were solid-fueled. The principal exceptions were large ground-launched types such as the V-2 and some of the guided missiles.

Guided missiles were among the most spectacular developments to come out of World War II. The hard-pressed Germans developed a variety of rocket-propelled missiles intended for use against airborne and surface targets. One of these was the Hs 293, which was launched against Allied vessels. The *Schmetterling* was an antiaircraft missile which probably would have become the V-3. It had a wing span of over 6 feet, was more than 11 feet long, and was propelled by a jettisonable booster rocket installation. It had just reached the production stage when the war ended. The Germans were then in the process of developing several other rocket-propelled guided missiles, including the *Feuerlilie,* the *Rheintochter,* and the *Wasserfall.* The latter was 25 feet long and weighed 4 tons when fueled. Most of these early guided missiles had a bizarre appearance, and the American designs were no exception. For example, the Navy's "Gorgon" was a rocket-propelled canard. It was one of several types under development in this country at the close of the conflict.

Upper-Atmosphere Research with Rockets

Goddard's death occurred just as World War II ended. Nevertheless it was his lifelong goal, that of using the rocket for upper-air studies, that became one of the principal objectives of American postwar rocket research. The GALCIT Jet Propulsion Laboratory was, in fact, already engaged in developing the Army's Wac Corporal[12] with this end in mind. The Wac Corporal attained an altitude of 44 miles; however, it fell short of meeting the needs of the postwar upper-atmosphere research programs. Accordingly, the development of a larger version, known as the Aerobee,[13] was begun under Navy sponsorship. Even the martial V-2 was harnessed for peaceful purposes. Captured German V-2s, launched by the Army Ordnance Department at its White Sands Proving Ground, have been used extensively for high-altitude research.[7,14] Looking forward to the day when the supply of V-2s would become exhausted, the Naval Research Laboratory initiated the development of the Viking, a rocket designed to serve the upper-air research program more effectively.[15]

The use of this variety of high-altitude vehicles for scientific exploration is coordinated by the Upper Atmosphere Rocket Research Panel. This board, originally known as the V-2 Upper Atmosphere Research Panel, was established early in 1946.[14] The scope of its activities widened as the American high-altitude sounding rockets became available, and in 1948 its name was changed to the Upper Atmosphere Rocket Research Panel. The panel is now composed of representatives of the Applied Physics Laboratory of The Johns Hopkins University, the General Electric Company, the Air Materiel Command, the Ballistic Research Laboratories of the Army Ordnance Department's Aberdeen Proving Ground, the California Institute of Technology, the Evans Signal Laboratory, the Harvard College Observatory, the University of Michigan, and the Naval Research Laboratory. In addition, other institutions participate in the program from time to time. The research is conducted chiefly in V-2, Aerobee, and Viking rockets.

The Aerobee was developed jointly by the Navy-sponsored Applied Physics Laboratory of The Johns Hopkins University, the Aerojet Engineering Corporation, and the Douglas Aircraft Company. It is 15 inches in diameter, 20 feet long, and weighs about half a ton. Pay loads of up to 250 pounds can be carried in the instrumentation section, which occupies the forward 88 inches of the fuselage. The Aerobee is a representative of a class of large rockets that do not incorporate a control system of the type found in the Viking and the V-2. The Aerobee is launched from a tower as shown in Figure 9. After it leaves the tower it is stabilized aerodynamically by the action of its tail fins, and the trajectory is controlled by tilting the tower appropriately. Launching is accomplished with the aid of a solid-fuel booster rocket, which imparts a velocity of

about 1,000 feet per second. The booster then drops away, and the liquid-fuel motor of the rocket proper operates for about 45 seconds. The Aerobee has reached a maximum velocity of approximately 4,400 feet per second and an altitude of about 78 miles.

The Viking also represents a cooperative effort. The propulsion system is designed and built by Reaction Motors Incorporated. The fuselage, fuel tanks, fins, and accessories are engineered and constructed by the Glenn L. Martin Company. Technical direction of the Viking development is maintained by the Naval Research Laboratory. The Viking power plant uses liquid oxygen and alcohol as propellants, and develops an effective exhaust velocity of about 6,500 feet per second and a thrust of 10 tons. Fuel injection pressure is generated by a turbopump, which is driven by the decomposition of hydrogen peroxide. The Viking is steered by appropriately altering the direction of the rocket motor axis. This is another of the many techniques developed by Goddard. The Viking is now 48 feet,

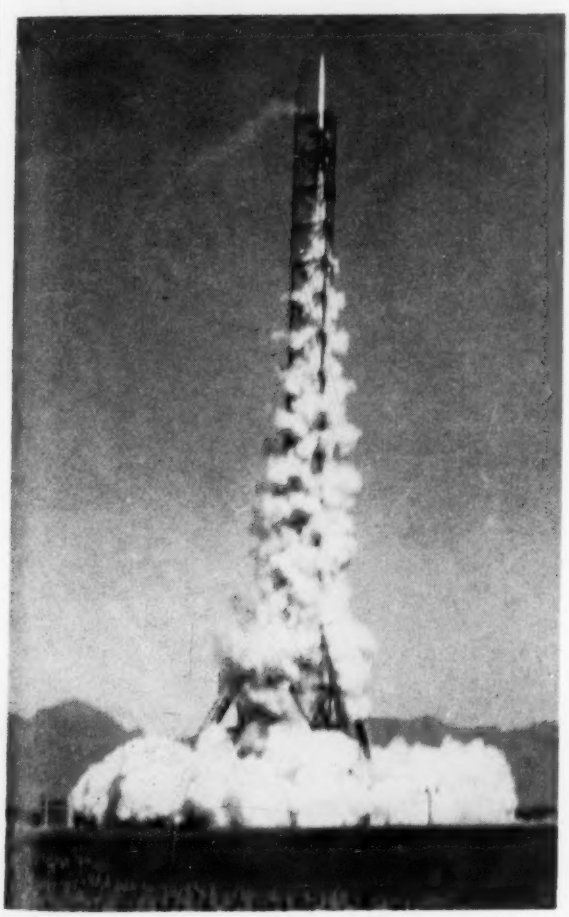

FIG. 9. The Aerobee emerging from its launching tower.

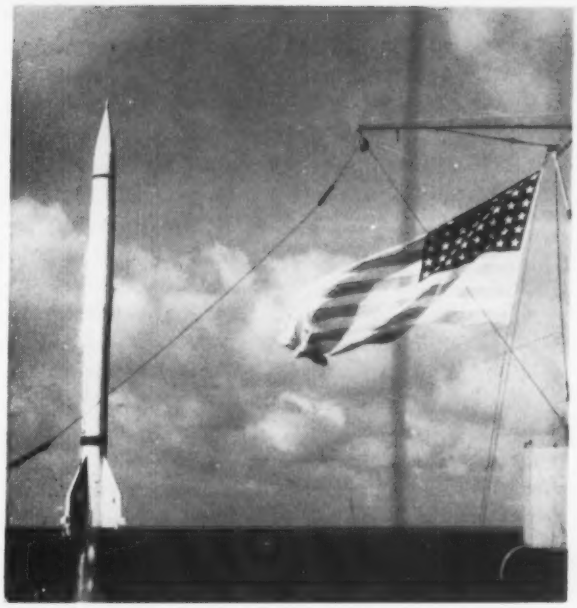

FIG. 10. Launching the Viking from the U.S.S. *Norton Sound* at the equator. A shower of ice particles shed by the rocket is seen at the left. A shock-wave pattern is clearly visible in the jet.

7 inches tall, 32 inches in diameter, and weighs more than 5 tons when fueled. The forward compartment of the rocket, 102 inches long, is reserved for upper-atmosphere research instrumentation, and additional space for this purpose is available in other parts of the missile. The Viking can carry pay loads ranging from 100 pounds to a ton. With a 100-pound pay load it has a propellant mass ratio of about 0.75, the highest ever achieved. It is the first American rocket to attain an altitude in excess of 100 miles.

An adequate understanding of the earth's upper atmosphere cannot be had without knowledge of its behavior at different times in the diurnal and annual cycles and at a number of important regions around the globe. One method of attacking the latter problem is to utilize ships as mobile launching platforms. Such a program has already actually been inaugurated. Aerobee and Viking rockets have been fired from the deck of the U.S.S. *Norton Sound* at a number of key locations in the Pacific Ocean. For example, on May 11, 1950, a Viking was flown to an altitude of over 106 miles from a point near the intersection of the geographic and geomagnetic equators. This Viking, shown in Figure 10 as it took off, carried almost half a ton of research equipment, which was designed and installed by the Naval Research Laboratory for the study of the primary cosmic radiation and the pressure and temperature of the upper atmosphere.

The rocket has become a useful tool in the hands of scientists working through the Upper Atmosphere Rocket Research Panel. More than half a hundred large rockets have been launched under the program. New knowledge has been gained about cosmic rays, the solar ultraviolet spectrum, the ionosphere, the earth's magnetic field, and the temperature, pressure, and composition of the earth's upper atmosphere. High-altitude photographs not only possess an intrinsic interest but also furnish valuable information to the meteorologist. Almost all these phenomena could be studied only by indirect methods, if at all, prior to the availability of the high-altitude sounding rocket. More extensive accounts of upper-atmosphere research with rockets are given by Newell.[16,17]

The high-altitude research program contributes to rocket development in several ways. It makes known many essential facts about the regions through which rockets travel. Radio telemetering systems, such as those developed by the Naval Research Laboratory[14,18] and the Applied Physics Laboratory[19] for use in the upper-air studies, have also proved their value as rocket research tools. They have been used to study the performance of rockets such as the V-2, the Aerobee, and the Viking during actual flights on numerous occasions.

The Naval Research Laboratory has also developed two major safety devices which serve to increase greatly the effective area of the White Sands Proving Ground. They are a radio-operated, emergency fuel cutoff system[14] and a rocket impact predictor. The predictor continuously computes the point at which a rocket will land if the thrust ceases immediately. The thrust can be terminated at any instant by using the emergency radio control to cut off the flow of fuel to the rocket motor. These two instruments are particularly valuable in case of an erratic flight when the rocket gives evidence of landing dangerously near to the edge of the firing range. They make it possible to extract the maximum altitude consistent with range safety. In this way they considerably increase the launching program's value both to upper-air and to rocket research.

The aerodynamicist also derives benefit from rocket research. The rocket-propelled X-1 is the first manned American airplane to exceed the speed of sound. It was developed for the purpose of investigating the phenomena associated with supersonic flight. The X-1 was designed and built under the joint supervision of the Air Materiel Command and the Bell Aircraft Corporation, in coordination with the National Advisory Committee for Aeronautics. Reaction Motors Incorporated constructed its power plant, which consists of four rocket motors.[20] The unit uses liquid oxygen and a mixture of alcohol and water as fuels and can develop a thrust of 6,000 pounds for about 2.5 minutes. The airplane weighs approximately 13,000 pounds at take-off. When viewed as a rocket, it has a propellant mass ratio of about 0.6. The X-1 has already flown hundreds of miles per hour faster than the speed of sound. The X-1A, an improved version designed to reach a speed of 1,700 miles per hour, will be flight-tested soon.

A glimpse of the future was provided on February 24, 1949. On that day, less than twenty-three years after Goddard launched the world's first liquid-fuel rocket, a large two-stage missile consisting of a Wac Corporal mounted in the nose of a V-2 was fired at the White Sands Proving Ground. Figure 12 shows the "Bumper" shortly after take-off. The Wac Corporal was launched from the V-2 after one minute of flight at an altitude of twenty

FIG. 12. The "Bumper" on its way to an altitude record. This picture of a Wac Corporal in the nose of a V-2 was taken just after take-off on February 24, 1949. The Wac Corporal reached an altitude of 250 miles less than seven minutes later.

miles and at a velocity of one mile per second. It went on to attain a peak altitude of 250 miles and a velocity of about 5,200 miles per hour, or about seven times the speed of sound. The highest altitude previously attained by a man-made vehicle was 114 miles. This was reached by a V-2 fired at White Sands on December 17, 1946.

Increasingly larger testing ranges will be required as the performance of rockets improves. A long-range proving ground, based at Cape Carnaveral on Florida's east coast, is now being developed to meet the nation's needs. A chain of observation stations extending hundreds of miles into the Atlantic is to be located in the Bahamas. Bumper missiles have already been fired from the launching area, which is now known as the Patrick Air Force Base.

The rocket represents a major step forward, but it penetrates beyond the lower atmosphere relatively infrequently, and then only for brief periods. The establishment of an Earth satellite would permit the making of continuous observations of many of the phenomena now being studied only intermittently by rocket probing.

When he was a freshman at Worcester Polytechnic Institute not long after the turn of the century, Goddard received an assignment to write a paper on "Traveling in 1950."[1] In it he detailed a proposal for a railway that would transport passengers from New York to Boston in ten minutes. The railway he envisioned then has not materialized, but in its place we now have rocket vehicles embodying many of the principles and techniques which he developed. Among them are the V-2, which could actually complete such a journey in about half the time he allotted, and rocket airplanes such as the X-1, in which man may soon be able to travel the distance between New York and Boston in ten minutes.

In terms of travel time, the rocket-propelled passenger aircraft of the future will bring the earth's national capitals as close to the world capital in New York as America's state capitals are to Washington today.

The development of rockets capable of navigating interplanetary space will probably continue to be the ultimate goal of rocket research. One can only speculate upon the sequels of its achievement.

PICTURE CREDITS: Figure 1 is from Goddard's *Liquid-Propellant Rocket Development* (Washington: Smiths. Inst., 1936); Figures 2, 3, and 4 are from Goddard's *Rocket Development* (New York: Prentice-Hall, 1948); Figure 5, from Willy Ley's *Rockets and Space Travel* (New York: Viking, 1947); Figure 8, from Pendray's *The Coming Age of Rocket Power* (New York: Harper, 1945); the others are official Department of Defense photographs. All are used by special permission.

References

1. GODDARD, R. H. *Rockets.* New York: American Rocket Society, 1946.
2. ———. *Rocket Development.* New York: Prentice-Hall, 1948.
3. LEY, W. *Rockets and Space Travel.* New York: Viking, 1947.
4. *Astronautics,* (54), 10 (1943).
5. SANGER, E. *Recent Results in Rocket Flight Technique.* Washington: Nat. Advisory Com. for Aeronautics Tech. Memo. No. 1012, 1942.
6. PENDRAY, G. E. *The Coming Age of Rocket Power.* New York: Harper, 1945.
7. RIVKINS, H. *Army Ordnance,* **31**, 429 (1947).
8. VON BRAUN, W. *J. Brit. Interplanet. Soc.,* **9**, 87 (1950).
9. *Astronautics,* (49) 4 (1941).
10. *Ibid.* (35), 17 (1936).
11. BURCHARD, J. E. *Rockets, Guns and Targets.* Boston: Little, Brown, 1948.
12. MALINA, F. J. *Army Ordnance,* **31**, 45 (1946).
13. VAN ALLEN, J. A., FRASER, L. W., and FLOYD, J. F. R. *Science,* **108**, 746 (1948).
14. *Upper Atmosphere Research Report No. I,* various authors. Naval Res. Lab. Rep. R-2955. Washington: 1946.
15. SMITH, C. H., JR., ROSEN, M. W., and BRIDGER, J. M. *Aviation,* **46**, (6), 40 (1947).
16. NEWELL, H. E., JR., *Sci. Mon.,* **64**, 453 (1947).
17. ———.*Trans. Am. Geophys. Union,* **31**, 25 (1950).
18. BEST, N. R. *Electronics,* **23**, (8), 82 (1950).
19. MELTON, G. H. *Electronics,* **21**, (12), 106 (1948).
20. SHESTA, J. *Aviation,* **46**, (1), 44 (1947).

SCIENCE ON THE MARCH

ON THE HISTORY OF FOOD PRESERVATION

THE remark of Core about Western civilization that "the origin of many important discoveries lies buried in the obscurity of past ages, is as true in the field of food preservation as elsewhere. The art of food preservation is by no means so new as many people are inclined to think. It is as old as the history of man and no doubt even older. The Cyclopes described by Ulysses as a pastoral people, who were "a savage kind not tamed by manners nor by laws confined," had in their caves "full pails and vessels of the milking trade and shelves with loads of cheese pressed." Butter, also, must have been well known in many parts of Europe and Asia in prehistoric times, because Pliny said of it that it was "the most luxurious food of barbarous people." The same writer reported that Zoroaster lived for twenty years in the desert on cheese that had been so treated as not to be affected by age.[1] Hesiodus, in his *Ontogonia,* speaks of the art of preservation; Herodotus mentions fruit preserved during the wintertime; Diodorus, of Sicily, described various extracts prepared by the ancient Egyptians; and Warro, Pliny, and Apilio gave several recipes for the preservation of various foods.

In general, the information we have from these writers concerning the preservation of food shows that ancient people, in ordinary seasons, were almost well equipped to meet their needs for food. Their methods and practices based on mere observation or accident did lack modern scientific character, but served nevertheless the same purpose. By observing that overripe fruit dried on the tree would keep longer, primitive man was led to develop methods of drying fruit and other food in the sun. The use of salt, natural ice, and snow for the preservation of food, extensive then as it still is, especially in underdeveloped countries, came about as a result of similar observations. Animals accidentally covered by snow, or fish that remained in saline waters, cut from the main seas, were well preserved for some time and gave rise to such processes as icing and salting of food. Accidental fermentation of grape juice or curdling of milk led to wine making and the preparation of cheese. Similar observations on what happened to meat and fish hung over the fire helped in the development of preservation by smoking. And there is no doubt that the preparation of butter was originated by nomad races of pastoral people who, during their wanderings, carried with them milk in wooden barrels and other containers.

It was quite natural that at a time when scientific knowledge did not exist progress was very slow. That eggs, oils, and other food products could be preserved at all is surprising. For example, the process of preserving eggs in limewater, which is almost as good a way as any other, was known in China long ago. Salt-curing and smoking of meat were old practices even in the time of Homer (1000 years B.C.). The Iron Age people of Northern Europe practiced salt preservation, drying, and refrigeration of meat products. The importance of salt is shown by the etymology of the word "salary" —*salarium,* or allowance of salt. The Romans had meat shops closely resembling those of today, especially those of Europe, and they were conducted in a sanitary fashion.[2] Phoenician merchants used to ship salted fish to Jerusalem. Various documents show that as early as A.D. 1230 fishhouses and "black houses" for the fumigation of herring existed in England, Holland, and France.[3] Vegetables preserved through lactic acid fermentation were well known to the Teutonic people of North Europe. The Latin writer Apicius gave recipes for preserving meat in honey without salt, or for keeping cooked sides of pork by using a pickle of mustard, vinegar, salt, and honey. This method is still in use in France and central Europe. Similar recipes for the preservation of olives were advocated by Palladius in the fourth century.[4] It is a fact that the Jews established their rabbinical laws with an insight into bacteriology. The ancients were aware, also, of the detrimental effect of air upon the preservation of certain foods and, according to Pliny, Vitruvius, and Didimos, used various means such as resin, balsam, oil, and sawdust to prevent its action. Resin, especially, was used extensively in the preparation and preservation of wine by the ancient Greeks, and is still used by wine makers in many parts of Greece. It serves for preservation and at the same time imparts certain desirable qualities to the wine. Also, the use of gypsum for the preservation of wine was described by Dernocritus and quoted by Kassianos (a Greek writer of the tenth century) in his book *Geoponica.*[6]

If we turn to refrigeration, the specialty of the

modern food preservationist, we find that ancient knowledge in the field was not so negligible. The accumulation of snow and ice and their storage in insulated cellars were practiced in the eleventh century B.C. by the Chinese for the purpose of cooling drinks. In Egypt, where no natural ice is ever formed, artificial refrigeration was first initiated. On Egyptian frescoes of 2,500 years ago, we see slaves waving fans in front of earthen vessels filled with water. The Greek sophist Protagoras, who visited Egypt in the fifth century B.C., described how the people put water-filled jars on the roofs of their dwellings in order to cool them. The Roman emperor Varius Avitus (Heliogabalus) went even further; he ordered his servants to make a mountain of snow in his garden to keep his palace cool during the summer. He and the caliphs of Bagdad and Damascus actually originated air conditioning. The latter used to fill the space between the double walls of their summer palaces (purposely so constructed) with snow to keep them cool. In India, where the nights must have been cloudless and the air very dry, they were able to make ice one and a half inches thick by placing porous jars of water upon thick beds of straw at sunset.[5] Even ice cream, our delight today and the pride of our modern milk industry, was not totally unknown in ancient days. Something like ice cream was known to the Romans under the name *aphrogalla,* which Conrad Gesner supposes to have been the same as the preparation mentioned by Galen in the second century under the name *melca.*[7] Other biological processes affecting preservation of juices and the effect of temperature and other factors upon them were well understood by the people of antiquity, as is shown by recipes such as the following: "If you wish to have grape juice throughout the year put it in an amphora, cover the cork with pitch and lower it into the fish pond. After thirty days take it out. It will remain grape juice through the whole year."[6]

Even in the field of gas storage and the use of antioxidants, the latest achievements of the industry of food preservation, ancient people had something to say. Here is one of the several recipes given by Kassianos Vassos for the preservation of grapes: "It is advisable," he said, "to hang grapes inside a crock containing must, so that they touch neither the must nor each other. Under such conditions, the grapes will be preserved as well as if they were just cut off the vines."[6] Even more complicated methods, such as the combination of "water feeding" and carbon-dioxide storage, which only recently have been the object of investigation in Cambridge, England, were known to the ancients.[6]

In a paper dealing with natural antioxidants,[8] valuable ideas are suggested by Kassianos in *Geoponica.* It is highly probable, also, that similar information given by Cato[9] in recipes for the treatment of oil storage jars with gum arabic and other substances helped in the discovery and use of dehydroquaretic acid as an antioxidant. Another of Cato's suggestions, which shows insight into the process of enzyme inactivation, was to wash olives in boiling water before extracting the oil. Before the name enzyme was ever known, methods for preventing enzymatic discoloration of potatoes during sun-drying were also used by the inhabitants of Peru, according to Francis de Castelnau, and a freezing treatment was given to potatoes in order to facilitate drying.[10] Plant injections, another supposedly novel idea of modern science, were known in a more simplified form[6] and applied for practical purposes long ago, according to Tarantinos. The same is true of plant selection, artificial pollination, and a good many other practices.

The impact of science within the past two or three centuries gave an impetus to the development of food preservation processes and a new orientation to the whole movement, the orientation toward scientific experimentation. Where before there was only art, a new applied science has begun to develop slowly and steadily. The discovery of sugar in beets by Marggraf marked the beginning of a wide application of this substance for fruit preservation. The invention by Nicholas Appert during the Napoleonic wars, of airtight containers, marked the beginning of the canning industry. Other inventions by Perkins (1835), Caré (1860), and Linde (1885) led to the creation of modern artificial refrigeration, which plays such an important role in our life today. But before all these inventions could appear, more fundamental scientific discoveries in various fields had to be made. Spallanzani, Pasteur, Faraday, Joule, Thompson, and others were real pioneers in food preservation as well as in other sciences. It would take too much time and space to extend here this kind of discussion to other fields of human activity through man's history, but I believe that it would be of value to scientists in general to look back on the various details of life in past ages. It is quite possible that a study of the methods and practices used then, made in the light of present-day scientific knowledge, might suggest new ideas to scientists who, overwhelmed by modern techniques, high specialization, and the prevailing positivistic views in research, seem unable to use their imaginations to the fullest extent, as our forefathers did. There is something discouraging about modern trends in the

development of food preservation, as well as in other industries. The rate of movement is too fast and perhaps not in the right direction. Process after process and machine after machine are being developed, at such speed that even the very specialists in the field cannot keep abreast of the progress. What really makes the difference between previous stages of scientific progress and progress today is the increased rate of development, not so much in new ideas, but in new techniques and equipment. We live actually in a feverish period, a period of developing and using machines in everything and for everything. It seems to me that present evolution toward making machines, in our system, resembles the scheme of other biological processes under the impact of heat. In the beginning the growth is slow; as the temperature rises the growth becomes faster and faster, until a maximum is reached. Then the growth begins to fall, and even stops entirely if the continuously rising temperature is not put under control. I begin to suspect that we, also, are approaching such a maximum under the stimulus of a self-developed fever of making machines. Let us hope that some kind of automatic control exists in such a process of evolution, and that it will be put into operation in time, before the ever-growing fever of making and using machines reaches the point of making life impossible.

References

1. Bostock, J., and Riley, H. T. *Pliny, Natural History.* London, Bell & Sons, 1892. Bk. XI, p. 85; Bk. XIV, pp. 237, 264, 267; Bk. XV, pp. 285, 303; Bk. XVIII, p. 104.
2. Jensen, L. B. *Microbiology of Meats.* Champaign, Ill., Garrard Press, 1945, p. 2.
3. Emmanuelle, F. *Industria delle conserve.* Milan, Ulrico Hoepli, p. 4.
4. Kaloyereas, S. A. *Fruit Prod. J.,* (1928).
5. Plank, R. *Deutsches Mus Abhandlungen u Berichte,* **12,** (5) (1940).
6. Kassianos, V. *Geoponica.* Athens, Ministry of Agric., 1930.
7. Kaloyereas, S. A. *Milk Dealer,* (Oct. 1948).
8. ———. *J. Am. Oil Chem. Soc.,* **24,** (2), 39 (1947).
9. *Cato the Censor on Farming.* (Trans. by Ernest Brehaut.) New York, Columbia Univ. Press, 1933.
10. Rose, E. *Histoire de la Pomme de Terre.* Paris, Rothschild, 1898, p. 27.

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New Books Received

Table of the Bessel Functions $Y_0(z)$ and $Y_1(z)$ for Complex Arguments. Prepared by National Bureau of Standards. xl + 427 pp. + 23 Tables. $7.50. Columbia University Press. New York. 1950.

1940 E. W. Scripps Cruise to the Gulf of California. Charles A. Anderson, *et al.* Illus. Geological Society of America. New York. 1950.

Some Applications of Statistics to Archaeology. Oliver H. Myers. vi + 37 pp. + 19 Figs. Government Press, Cairo. 1950.

Masks as Agents of Social Control in Northeast Liberia. George W. Harley. xiv + 45 pp. + 15 collotype figures. $3.25. Peabody Museum of Archaeology and Ethnology, Harvard University. Cambridge, Mass. 1950.

Studies in Muslim Iconography. I. The Unicorn. Richard Ettinghausen. xii + 209 pp. + 48 plates. $3.25. Smithsonian Institution. Washington. 1950.

The Physician Examines the Bible. C. Raimer Smith. vii + 394 pp. $4.25. Philosophical Library. New York. 1950.

The Private Life of the Protozoa. Winifred Duncan. ix + 141 pp. Illus. $3.00. Ronald. New York. 1950.

The Principles of Physical Geology. Victor E. Monnet and Howard E. Brown. vi + 450 pp. Illus. $4.50. Ginn. Boston. 1950.

Atlas of Human Anatomy. Barry J. Anson. xxi + 518 pp. Illus. Saunders. Philadelphia. 1950.

Survey of Modern Electronics. Paul G. Andres. x + 522 pp. Illus. $5.75. Wiley. New York. 1950.

Plants of Bikini and other Northern Marshall Islands. William Randolph Taylor. xv + 227 pp. + 79 plates. $5.50. University of Michigan Press. Ann Arbor. 1950.

A History of Philosophical Systems. Vergilius Ferm. xiv + 642 pp. $6.00. Philosophical Library. New York. 1950.

Methods of Mathematical Physics. Harold and Bertha Swirles Jeffreys. vii + 708 pp. $15.00. Cambridge University Press. New York. 1950.

Memorias do Instituto Butantan. Tomo XX. 351 pp. Illus. Instituto Butantan. Sao Paulo, Brazil. 1947.

From Atoms to Stars. Martin Davidson. 188 pp. Illus. $2.70. Macmillan. New York. 1950.

Botany. Wilfred W. Robbins and T. Elliot Weier. ix + 480 pp. Illus. $5.00. Wiley. New York. 1950.

United Nations Scientific Conference on the Conservation and Utilization of Resources. Vol. I, *Plenary Meetings.* lxi + 431 pp. Illus. $4.50. Columbia University Press. New York. 1950.

Halloween. Ralph and Adelin Linton. 108 pp. Illus. $2.50. Schuman. New York. 1950.

Mathematics of Relativity. G. Y. Rainich. vii + 173 pp. $3.50. Wiley. New York. 1950.

The Historic Approach to the Theory of Relativity. Vol. II. Mary Milbank Brown. ix + 279 pp. (No price given.) J. J. Augustin. New York. 1950.

The Primeval Atom. Georges Lemaître. Trans. by Betty H. and Serge A. Korff. ix + 186 pp. $3.00. Van Nostrand. New York. 1950.

Cell and Psyche. Edmund W. Sinnott. i + 121 pp. $2.00. University of North Carolina Press. Chapel Hill. 1950.

The Birds of North and Middle America. Herbert Friedmann. xiii + 793 pp. Illus. U. S. National Museum. Bulletin 50. Part XI. Smithsonian Institution. Washington, D. C. 1950.

Theory of the Interior Ballistics of Guns. J. Corner. xiii + 443 pp. Illus. $8.00. Wiley. New York. 1950.

Chymia. Henry M. Leicester, Ed. ix + 251 pp. Illus. (No price given.) University of Pennsylvania Press. Philadelphia. 1950.

BOOK REVIEWS

THE AGE OF SCIENCE

Mid-Century. The Social Implications of Scientific Progress. John Ely Burchard, Ed. xx + 549 pp. $7.50. Technology Press, MIT, Cambridge, Mass.; Wiley, New York; Chapman & Hall, London. 1950.

THIS book is a verbatim record of the discussions held at the Massachusetts Institute of Technology at its Mid-Century Convocation in the spring of 1949. Its editor is Dean of Humanities at MIT. The book is a long one; it requires (and is well worth) careful study. In this the reader will be aided by many footnotes and by a dozen appendices on important subjects that arose during the discussions.

The social implications of scientific progress were divided for discussion into three classes—material, spiritual, and intellectual—each class being discussed by a separate panel of speakers. In addition, there were opening addresses of a general character by Dean Burchard, Karl Compton, and Winston Churchill; and after the panel discussions were over there was a closing address by Harold Stassen, president of the University of Pennsylvania. The sessions closed with the inauguration of James Killian, Jr., as the tenth president of MIT.

Altogether, the speakers at the Convocation numbered three dozen, comprising statesmen, clergymen, scientists, economists, engineers, and businessmen. This variety of points of view gave the proceedings a character that could hardly have been improved upon for generality. In fact, flashes of humor even occurred occasionally, especially in the remarks of the physicist Sir Henry Tizard.

Early in the panel discussions the point was brought out that in actual practice material, spiritual, and intellectual problems cannot be thus neatly compartmented; and this point is illustrated in many places during the discussions. An interesting example is found in the address by Dr. Compton (p. 27), in which he spoke of the success that had been obtained by the use of synthetically manufactured hormones. Looking forward into the next half century, he ventured the speculation that material thought control was not beyond the range of possibility; that hormones might be produced that would cure a schizophrenic, or perhaps turn a general into a pacifist.

Another thought-provoking suggestion was made by Fairfield Osborn (p. 81). He says: "Man is adorned with a super-brain, the measureless asset that is his alone." Commenting on this in a footnote, the editor says: "That man's brain is a measureless asset is undeniable; but that it may not be an infinite asset begins to be suggested here and there." He quotes from a recent book by Norbert Wiener, of MIT.

The superiority of the human brain to others in the length of the neuron chains it employs is a reason why mental disorders are certainly most conspicuous and probably most common in man. . . . It is interesting to reflect that we may be facing one of those limitations of nature in which highly specialized organs reach a level of declining efficiency, and ultimately lead to the extinction of the species. The human brain may be as far along on its road to this destructive specialization as the great nose horns of the last of the titanotheres.

The realm of economics was not neglected. Speaking on the subject "The Role of the Individual in a World of Institutions," Senator Ralph Flanders discussed the questions that arise between organized labor and organized industry. The discussion which followed, and which is reported in dialogue form, was probably the liveliest at the Convocation.

The field of this book is much too broad to be covered in a brief review. The book is worth careful study, and may be recommended to the thoughtful lay reader as well as to specialists in the social and physical sciences.

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EXPERTLY DISSECTED

The Anatomy of Mathematics. R. B. Kershner and L. R. Wilcox. xi + 416 pp. $6.00. Ronald Press, New York. 1950.

THE first dictionary definition of anatomy is "the art" of dissecting, or artificially separating the different parts of any animal or plant, to ascertain their position, relations, structure and function." The subject of this art is usually dead, but not always. The second meaning is "the science, or branch of morphology which treats of the structure of animals." Substitute mathematics for animals and plants to get the definitions relevant for the authors' project. Their saws, knives, scalpels, and the rest are all in the kit of the modern axiomatic (or postulational) method. Axioms, as opposed to their use, have served mathematicians either as embalming fluid or the elixir of life. An example of the former was Euclid's somewhat primitive set of axioms for elementary geometry, which not only preserved that venerable body from corruption for about 2,000 years but petrified it completely. The use of axioms as an elixir to get a moribund subject to its feet again is mostly an activity of the twentieth century. The outcome has been astonishing. Things like arithmetic and algebra that seemed about to lapse into a state of eternal repose, suddenly started to move forward rapidly in response to the vigorous axiomatic kick administered by Hilbert at the turn of the century. For the past fifty years it has been axioms, axioms, axioms all the way, until axiomatics, to

some of its practitioners, appears as the only mathematics there is and the answer to all the mathematicians' prayers. The authors of this *Anatomy* are more restrained. They present several expert dissections and leave it to the spectator to admire or ignore.

Much of the material presented is customarily given in courses on abstract algebra, introductions to mathematical logic, the elements of set theory, and the systems of positive integers, positive rationals, and positive reals. By bringing all this and more together in an orderly development, the authors have made it possible for "at least a few so-called laymen . . . to learn what modern mathematics is like, without being expected to bring an elaborate technical education to lay upon the altar." The detail is elaborate. The authors start at a moderate depth, leaving unsounded such things as difficulties in connection with the concept of a set.

Numerous "projects" are proposed for the reader. The suggestions and answers given in an appendix supplement the text. If there are any destructive bugs lurking in the definitions, or axioms, or proofs, they should be detected when the book is used systematically with a class. Even if none are found, the search for them should keep the class awake.

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SMITHSONIAN'S FIRST SECRETARY

Joseph Henry: His Life and Work. Thomas Coulson. viii + 352 pp. Illus. $5.00. Princeton University Press, Princeton, N. J. 1950.

Joseph Henry died in 1878, and it is rather remarkable that not until now has there been a full-length biography of this eminent "natural philosopher" and "architect of American science." Mr. Coulson's book, which, incidentally, is the first adequate biography of any Smithsonian secretary, fills a conspicuous gap in our science history, and though it is not likely to be the last word, it is a very welcome one; for Joseph Henry, in spite of his "poor press," during and since his lifetime, was a great scientist and a great man.

Only recently I came upon a statement concerning Henry that illustrates a woeful misconstruction of the life of this man. The English physicist John Desmond Bernal (*The Social Function of Science,* Macmillan, 1939), discussing "promising scientists whose research work has been gradually but effectively sterilized by the entire absorption of their interest and time in administrative and teaching duties," adds this in a footnote: "One of the most tragic cases was that of Joseph Henry, a man of the same calibre as Faraday, who wasted most of his life as director of the Smithsonian Institution." There was nothing tragic about Henry, and such misconceptions of the importance of Henry's work after he left Princeton should be forever dispelled by Coulson's biography. Coulson shows that Henry not only "made the Smithsonian Institution the greatest influence upon American education for almost a century," but that this later period of his life was by no means a sterile one for him scientifically.

The author achieves an equally accurate and balanced appraisal of Henry's pre-Smithsonian work at Albany and Princeton, not unmindful of his shortcomings and limitations.

> In spite of the handicaps under which he worked [he says], Henry's achievements were sufficiently great to distinguish him as America's foremost physical scientist. . . . His discovery of electromagnetic self-induction is a scientific achievement of the first importance. . . . His contributions to electrical knowledge have been essential to practically every commercial application of electricity. . . . Henry also made several contributions to radio communication.

Mr. Coulson does not make Henry out as a god or an Einstein (he "lacked the divine spark of the superlative genius"), but I believe that this biographer has shown that Henry rightly belongs in the first-violin section of American physicists.

Particularly valuable, too, is Coulson's treatment of Joseph Henry's contributions to organized science exclusive of the Smithsonian Institution—the part he played, for example, in the founding of the National Academy of Sciences, the American Association for the Advancement of Science, and the Philosophical Society of Washington. One moot point, however, in Coulson's account is his thesis that the National Academy of Sciences was actually formed without Henry's knowledge; yet in the plate opposite page 278, captioned "The Founders of the National Academy of Sciences," Henry is included among the eight men pictured. This matter still seems to need clearing up.

The book is not without minor slips, as when the author says (p. 205) that today the botanical collections of the U. S. National Museum are "approaching a total of two hundred thousand specimens," when he means over two million; and there are several orthographical infelicities, such as the consistent misspelling of the surnames of Benjamin Peirce, Constantine Rafinesque, and James P. Espy and the given name of Sir Humphry Davy. The index has several unhappy omissions and blemishes that might have been obviated by a more assiduous indexer and a more alert proofreader.

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OIL

The Science of Petroleum—Crude Oils. Vol. V, Part I. Benjamin T. Brooks and A. E. Dunstan, Eds. viii + B + 200 pp. Illus. $11.00. Oxford University Press, New York. 1950.

Volume V of this series—which will be issued in three parts—is to deal broadly with the chemistry, physics, and chemical engineering of petroleum, and is essentially a supplement of Volume II, published in 1938.

The subject of the present volume (Part I) is divided

into Section 1, "Crude Oils," and Section 2, "Chemical and Physical Properties of Petroleum Hydrocarbons." A great deal of new information acquired in the past decade has been added. The crude oils of the United States from 1935 to 1945 are selected to represent the products of new fields developed in this period. Important data are presented on aviation base stocks from different crudes and the hydrocarbon composition of naphthas. New data on the physical and chemical properties of some Venezuelan crudes are given.

The information on Middle East crudes includes properties of those from the new fields of Saudi Arabia, Kuwait, and Qatar, as well as the older fields of Iran, Iraq, Bahrein, and Egypt. There are special process flow charts on crudes from Saudi Arabia and one on the distillation of Bahrein crudes.

The section on the evaluation of crude oil and its products outlines broad rules for estimating the value of petroleum fractions for specific uses from physical and chemical test data. This is an excellent chapter.

A special note is also introduced in the section on economic developments. This records increasing demands, reserves, and production in the past decade. It treats of world-wide developments in petroleum production, the increasing complexity of refining technology, prices, finance, investments, profits, and dividends.

The new sections on the separation and determination of the hydrocarbons in petroleum summarize the wealth of information which has been gained over the years since the first edition. Extensive tabulations show the hydrocarbons present in many natural and straight-run gasolines, thermally and catalytically cracked gasolines, kerosenes, gas oils, and lubricating oils. A discussion of crude oil classification by types is included, as well as new data on the hydrocarbon composition of waxes. A section on the fractionation, analysis, and isolation of hydrocarbons in petroleum describes the procedures developed at the Bureau of Standards under a grant from the American Petroleum Institute. Both apparatus and methods are described in detail, and flow charts for hydrocarbon analysis are given.

The original treatment of petroleum hydrocarbon chemistry has been revised. In the present volume, there are separate sections on the chemical reactions of paraffin, naphthene, aromatic, olefin, and diolefin hydrocarbons. A succeeding section on the mechanism of organic reactions develops the various theories relating to polymerization, alkylation, and other conversions.

Thirty pages are devoted to an extensive treatment of the chemical thermodynamic properties of hydrocarbons. A final section deals with high-pressure vapor-liquid equilibria in gas cycling operations in producing fields.

This volume contains important contributions to present knowledge of crude oils and petroleum chemistry. The present addition to the former volumes should be in the hands of everyone concerned with the properties and utilization of petroleum.

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THE LIFE OF SCIENCE

Immortal Magyar: Semmelweis, Conqueror of Childbed Fever. Frank A. Slaughter. 206 pp. $3.50. Schuman, New York. 1950.

SLAUGHTER has written a very straightforward account of the life of Dr. Semmelweis, whose early investigations into the causes and prophylaxis of puerperal fever represent one of the outstanding contributions to the progress of medical science.

The early life of Semmelweis is briefly treated, followed by more detailed accounts of the time he spent in Vienna and subsequently in Hungary compiling statistics and eventually propounding his theories. His outspoken and blunt criticism of officials in charge inevitably led to hostile feelings among his colleagues and undoubtedly postponed the recognition and acceptance of his important work for many years. His own reluctance to publish his finding has tended to cast some doubt on the priority of his work, but there is no doubt that he was advocating prophylactic measures before any of his contemporaries.

The persecutions which he suffered politically, professionally, and socially make his achievements more outstanding, for never did such an important finding have so much bitter and powerful opposition.

The gradual deterioration of Semmelweis and his tragic end are covered briefly, but the entire book is dedicated to his tireless efforts and those of his intimate friends to achieve universal recognition for his edict: "Wash your hands."

In the course of the narrative the author has included interesting side lights on the political situation of the times and its relation to medical practice in Europe. There are also accounts of the appalling conditions that existed in contemporary clinics and lying-in hospitals on the Continent.

The importance of the discovery of Semmelweis and its application to surgical as well as obstetrical procedures are noted in the light of the subsequent findings of Lister and Pasteur.

This volume is the fifteenth of the "Life of Science Library" and is an interesting and stimulating addition.

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NEW LIGHT ON OLD PROBLEMS

Plant Viruses and Virus Diseases. (3rd, rev. ed.) F. C. Bawden. xvi + 335 pp. Illus. $6.00. Chronica Botanica, Waltham, Mass.; Stechert-Hafner, New York. 1950.

THE study of viruses and viral diseases has proceeded so rapidly in recent years that a new and completely revised edition of Bawden's *Plant Viruses and Virus Diseases* is most appropriate and welcome. Each successive edition of this standard text has grown in size and completeness of coverage. The third edition presents one new and sixteen revised chapters. The new chapter is entitled Quantitative Methods of Assaying for Viruses; it discusses the use of various types of local

lesions and of precipitin tests for estimation of quantities of viruses. The revised chapters deal, respectively, with the nature of viruses, external and internal symptoms of infected plants, methods of transmission, vector relationships, viral mutations, serological reactions, purification, chemical and physical properties, crystallinity, particle sizes, types of inactivation, viral taxonomy, host plant physiology, control measures against viral diseases, and speculations on the nature and origin of viruses. Illustrations have been improved and increased in number. Subject and author indices are included.

As the author has wisely stated in a preface to his new edition, some omissions and shortcomings are inevitable in a text that attempts to cover a field of knowledge so complex and rapidly growing. The third edition reflects currently changing views of the relationships of viruses to their insect vectors, recent improvements in the technique of electron micrography, and advances in the understanding of serology and physical chemistry of viruses, types of viruses, transmission methods, and nucleic acid components.

The third edition, like its predecessors, is written in an interesting and readable style. It deals much with controversial questions, but in a way that is likely to stimulate the very research that is needed to settle them. In all probability some of the more controversial topics discussed in the present edition—such as vector relationships, particle shape, and viral taxonomy—will be better understood within the next few years as successive investigations throw new light on old problems. With clarification of old problems, however, will come gradual discernment of new ones. We may anticipate a need for continued revisions of Bawden's *Plant Viruses and Virus Diseases* to reflect our growing knowledge in this field of study. Successive editions have been, and may be expected to be in the future, a measure of our expanding grasp of the subject.

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BRIEFLY REVIEWED

Scientific Research: Its Administration and Organization. George P. Bush and Lowell H. Hattery, Eds., viii + 190 pp. $3.25. American University Press, Washington, D. C. 1950.

THE substitution of the word "development" for "research" in the title of this book would make it conform more nearly to the subject matter, which has been written for the most part, by administrative officers of large scientific laboratories. Since scientific development is now a two-billion-dollar-a-year enterprise, it is obvious that a considerable amount of administrative work is necessary, if only just to dispose of so large a sum.

Papers, presented at a symposium on the administration of scientific research and development at American University, comprise the subject matter of the book. These deal with coordination, planning, budgeting, scheduling, personnel, incentives, informational aids, and other subjects commonly considered in business administration, with special applications to laboratory administration. The editors have performed a valuable service in attempting to summarize the consensus of opinion as to just what constitutes the principles of administration applicable to laboratories. One cannot but feel, however, that the symposium missed an opportunity in not having present an equal number of scientific workers to criticize the proposals of the administrators. The problem is certainly two-sided, and, although most participants showed considerable understanding of the difficulties of applying conventional administrative procedures to laboratory activities, the danger of stifling initiative by many types of controls cannot be overemphasized.

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The Australian Environment. 183 pp. Illus. 102 *s.* 6 *d.* Commonwealth Scientific and Industrial Research Organisation. Melbourne, Australia. 1950.

THE reissue by the Australian Scientific and Industrial Research Organisation of the handbook prepared for the Conference on Plant and Animal Nutrition in Relation to Soils and Climatic Factors, held in Australia in 1949, has provided those interested in the Australian environment with a most useful and up-to-date book, which covers a wide range of subjects. There are nine chapters, dealing with the geography, climates, soils, agricultural development, water conservation and irrigation, vegetation, pastures, field crops, and livestock. The chapters are written by eminent specialists, but, as might be expected, not all summarize their data with equal success. Chapters 1, 2, and 4, written by Hills, Leeper, and Wood, respectively, are remarkably lucid and readable. Professor Wadham's account of the development of Australian agriculture is perhaps oversimplified, sixteen pages only being allotted to it. A better balance might have been got by giving less space to the chapter on sheep, cattle, and pigs in Australia and allowing Wadham a few more pages. The account of sheep, cattle, and pigs in Australia, though the third longest chapter in the book (twenty-four pages compared with an average of nineteen), makes no mention either of the manner in which the various European breeds of cattle have become acclimatized in Australia or of the particular breeds that have been introduced.

The book is well illustrated and contains some excellent maps, but unfortunately there is no index. In spite of these minor blemishes, it can be recommended to all those interested in Australian affairs.

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We're sorry: The third line of the listing of *Psychosexual Development in Health and Disease* (November, p. 347) should read "Grune & Stratton, New York. 1949."

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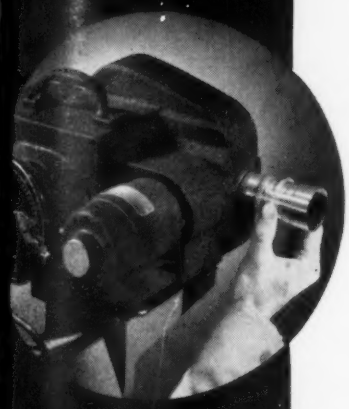

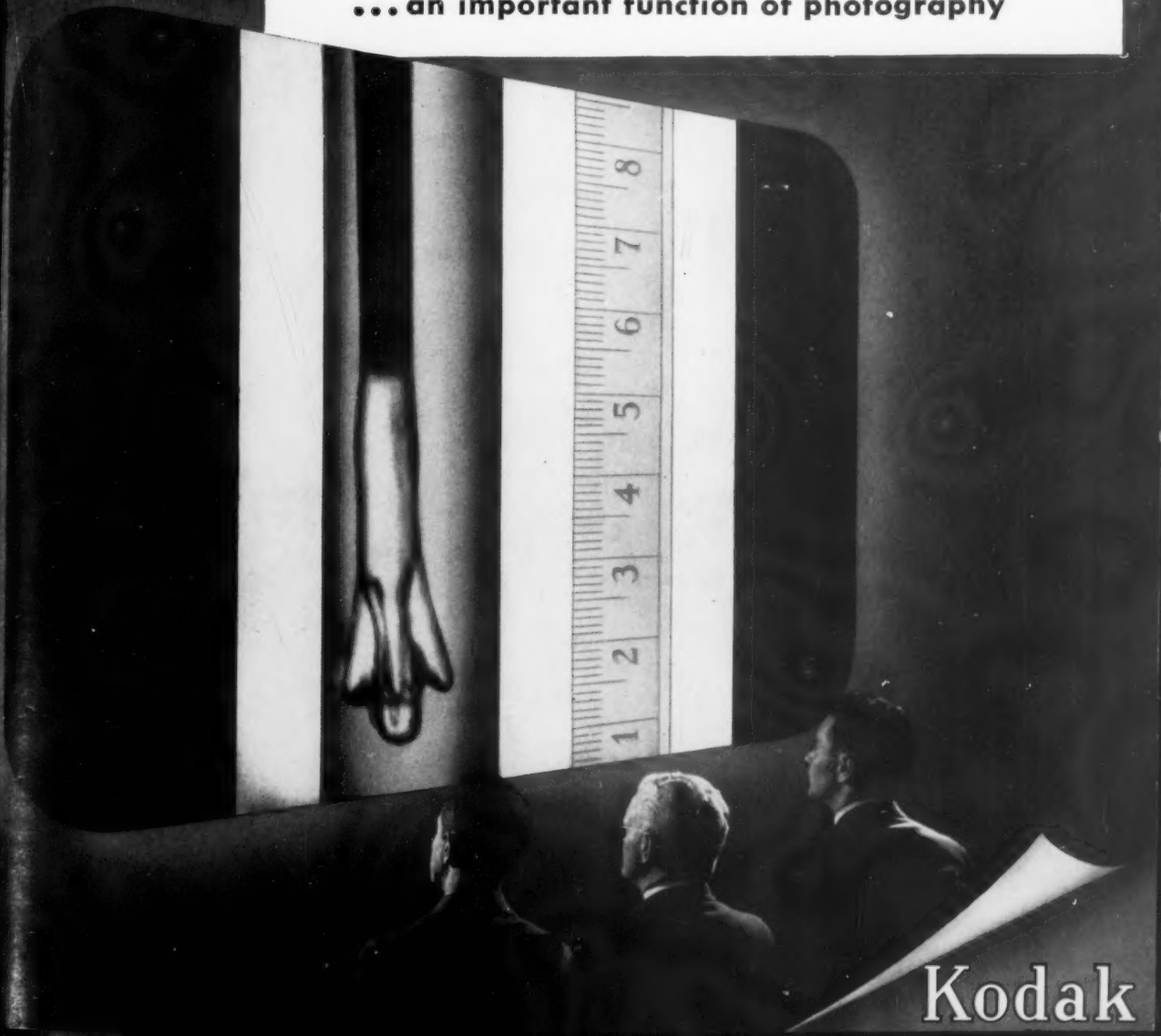

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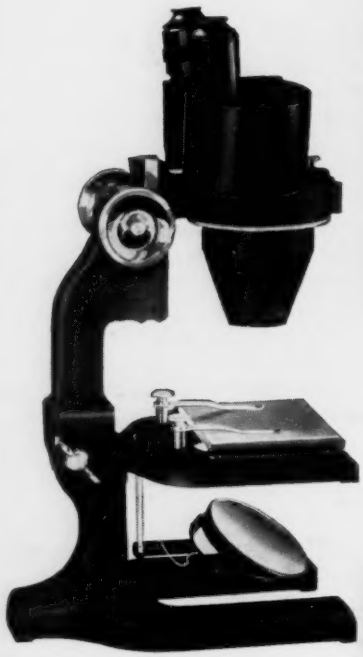

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